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DESCRIPTION OF THE EDISON STEAM DYNAMO.

By T. A. EDISON, Ph.D., and CHARLES T. PORTER.

[Read at the Philad'a meeting of the Amer. Soc. Mech. Engs., April, 1882.]

The central Edison station of the first district in New York City will, when fully equipped, be supplied with twelve dynamos, each of which is nominally rated as a 1200 light machine, at 16 candle-power incandescence, but is capable of supplying 1400 lights of this power, continuously, and with high economy, without heating the armature, or burning or injuring the commutator or brushes. This increased capacity is due to improvements in the lamp itself.

The armature of each dynamo is driven by a Porter-Allen engine, of $11\frac{3}{16}''$ diameter of cylinder by 16″ stroke, directly connected, and making 350 revolutions per minute, giving a piston travel of 933 feet per minute.

The steam is supplied by eight Babcock & Wilcox boilers, of 2000 aggregate horse-powers, and which will work under a pressure of about 120 pounds. These occupy the basement of the building. Over them, the first and second floors being removed, an iron superstructure is erected entirely separated from the walls of the building, and on this the combined dynamos and engines are placed.

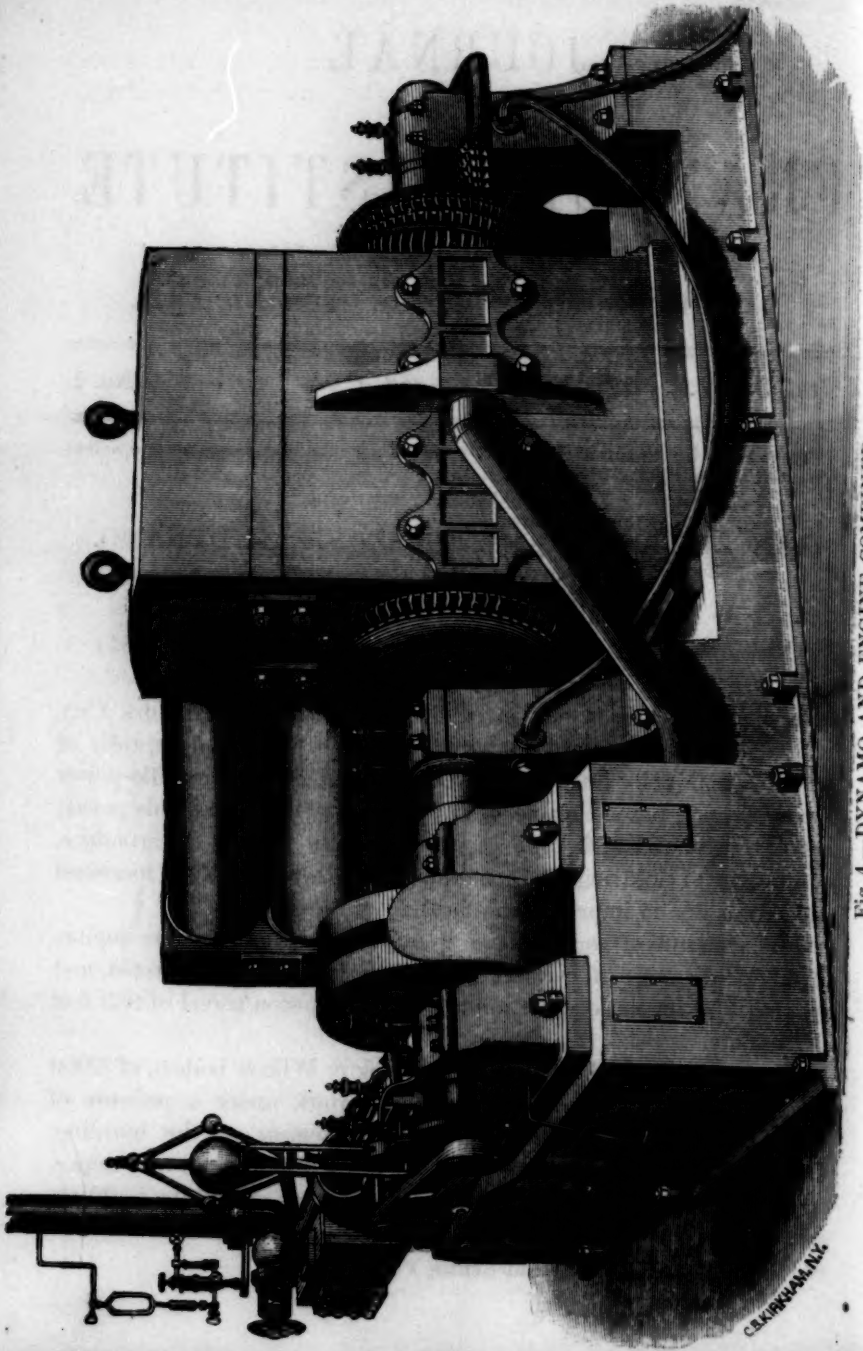


Fig. 4.—DYNAMO AND ENGINE COMBINED.

One-half of this equipment is now nearly ready for service, and the remainder is expected to be completed during the coming season.

The armature of the dynamo is of the form commonly known as the Siemens armature, but in its construction and "connecting up" it differs radically from all others.

The foundation of the armature, or the iron core which is built upon the shaft, is made up of sheet-iron disks, separated from each other by sheets of tissue paper, and bolted together. This has all the advantages of a solid iron core in strengthening the magnetic field, while it completely prevents the great loss of power by local currents, which would circulate in the iron if it were solid. In the place of insulated wires, the cylindrical face of the armature is made up of heavy copper bars, trapezoidal in section, each bar being insulated, and also separated from its neighbors and from the iron core underneath by an air space.

The connection between the bars on opposite sides of the armature, to form the electrical circuit, is made by copper disks, of the same diameter as the core. At each end of the core are one-half as many of these copper disks as there are bars, each disk being insulated from its neighbors, and the whole being bolted together in such a manner as to form, with the disks of sheet-iron constituting the core, one solid mass. Each disk is formed with projecting lugs on its opposite sides, to which the two bars are connected.

The connections between the opposite surfaces of an armature are of no benefit in generating an electric current, but are a necessary evil, introducing useless resistance into the circuit. By using for this connection copper disks in the manner described, a great weight of copper is disposed in a limited space, and so this useless resistance, and consequent loss of energy, is reduced to a minimum.

This method, moreover, reduces the work to a simple machine construction, in which all the parts are duplicates, and the operations can be much cheapened and facilitated by the use of special tools.

The spaces between the armature bars admit of a free circulation of air, thereby preventing the accumulation of heat, and increasing to an enormous degree the capacity of the machine. The armature is at intervals wound with piano wire over the bars to resist the centrifugal force developed by their revolution.

The commutator and brushes of an electrical machine are the parts subject to the greatest depreciation. In this machine all parts of the

end of the armature are so constructed as to be easy of access, and they can be quickly and cheaply repaired, or removed and replaced by new parts, when necessary. Any accident would require but a short stoppage for repairs.

Provision is made for keeping a continuous and rapid circulation of air over the entire face of the armature.

This armature is 27·8″ in diameter by 61″ long. The commutator adds 18″ to this length, and is itself 12¾″ in diameter. The armature shaft is of steel, 7¾″ in diameter, having a total length of 10′3″. The journals are 6½″ in diameter by 15″ long, and run in Babbit metal bearings in pillow blocks of the box form, giving the greatest stiffness with minimum of weight.

Provision is made for continuous water circulation underneath the boxes, and for continuous lubrication, with traps to prevent the creeping of the oil along the shaft and reaching the commutator, and drains to receive it as it runs through the bearings and convey it to a drip pan.

The magnet is made up of two immense cast iron "pole pieces," between the semi-cylindrical faces of which the armature revolves, twelve cylindrical soft iron cores attached to these pole pieces, and made magnetic by an electrical current circulated in the wire wound around them, and four soft iron keepers connecting the back ends of the cores. Eight of the cores are attached to the upper pole piece, and four to the lower one.

The width of these "poles" is 49″, and their height 61½″. The length of the twelve soft iron cores is 57″, the diameter of the eight upper ones is 8″, and of the four lower ones 9″.

The four soft iron keepers are each 11″ wide by 9″ in thickness, and the total length of the magnet is 94″.

The magnet is insulated by cast zinc bases 3″ in thickness.

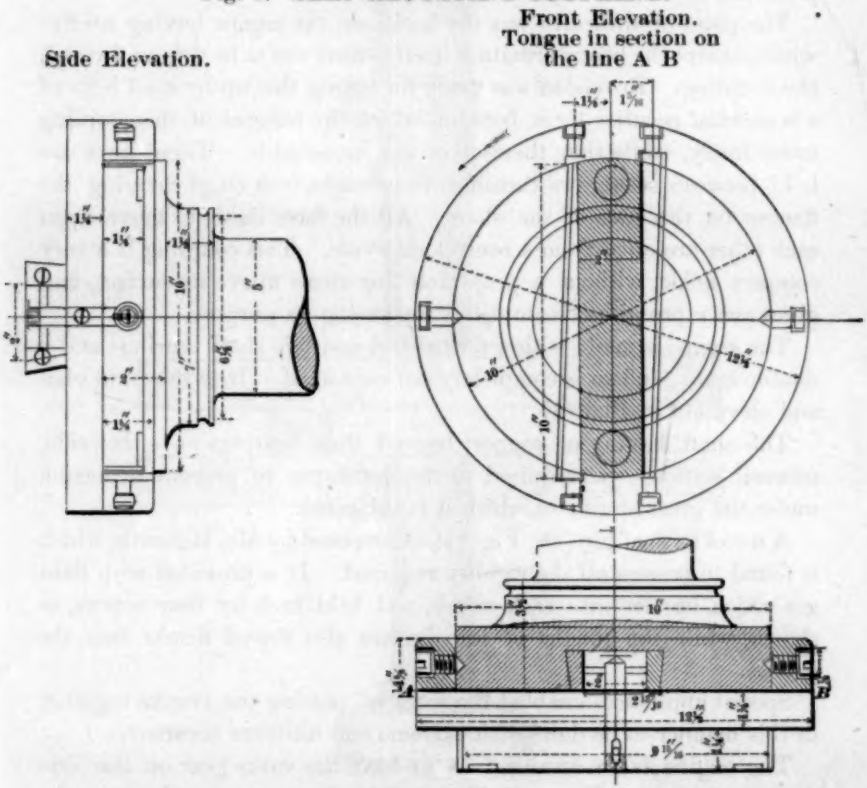
The weight of the dynamo is as follows:

Armature and shaft,	9,800 lbs.
Two pillow blocks,	1,340 "
Magnet, complete,	33,000 "
Zinc bases,	680 "
Total,	44,820 lbs.

The copper is distributed as follows:

In the armature bars, . .	590 lbs.
" " disks, . .	1,350 "
" magnet wire, . . .	1,500 "
Total, . . .	3,440 lbs.

Fig. 1. SELF-ADJUSTING COUPLING.



Mr. Edison was early impressed with the conviction that to give steady and reliable motion to these armatures it would be necessary to connect an engine to each one of them directly. This combination has been termed by him the STEAM DYNAMO.

In adapting the Porter-Allen engine to this service, a special construction in some respects was found to be called for. These special features will be briefly described.

It seemed important to avoid a rigid connection between the engine and the armature shafts, which would require the entire series of bearings to be maintained absolutely in line. In place of this, therefore, a self-adjusting coupling has been introduced, of the form shown in Fig. 1, and illustrated by a working model, which will permit of considerable errors of alignment without any abnormal friction being produced in the bearings.

The point of difficulty was the backlash, the engine having no fly-wheel, except the heavy armatnre itself, which was to be driven through the coupling. Provision was made for taking this up by steel keys of a somewhat peculiar form, between which the tongues of the coupling move freely, while they themselves are immovable. These keys are held between set-screws threaded in wrought iron rings covering the flanges on the ends of the shaft. All the faces liable to move upon each other are oiled from a central reservoir. This coupling is a very compact affair, without a projection anywhere above its surface, and gives every promise of completely answering its purpose.

The engine is made with a forked bed and two shaft bearings and a double crank, and so is completely self-contained. It is shown in plan and elevation in Plate 1.

The shaft having no support beyond these bearings on either side, unusual stiffness was required in the crank-pin to prevent deflection under the great strains to which it is subjected.

A novel form of pin (see Fig 2) was proposed by Mr. Richards, which is found to possess all the rigidity required. It is provided with flanges which are let into each crank, and held each by four screws, as shown, while the shanks of the pin are also forced firmly into the cranks.

Special appliances enabled the work of putting the cranks together in this manner to be done with extreme and uniform accuracy.

The engine is so arranged as to have the valve gear on the side furthest from the dynamo. The engineer has not to go between the engine and dynamo, when running, for any purpose.

The connecting-rod (Fig. 3), is of steel, and the crank-pin boxes are formed directly in the end of it.

This end is finished from a solid forging, and chambered out for Babbit metal. The bolts are then fitted, after which it is parted and holes are drilled for holding the Babbit securely.

In the connecting-rods for single crank engines of this type per-

manent length of rod is secured by forming the crank pin end solid, and taking up the wear by a wedge closing up the inside box. In these double crank engines this construction is impracticable, but the same object is attained by forming the crosshead end in the manner shown, in which the strap is made permanent and the inside box is closed up by a key bearing against a steel plate.

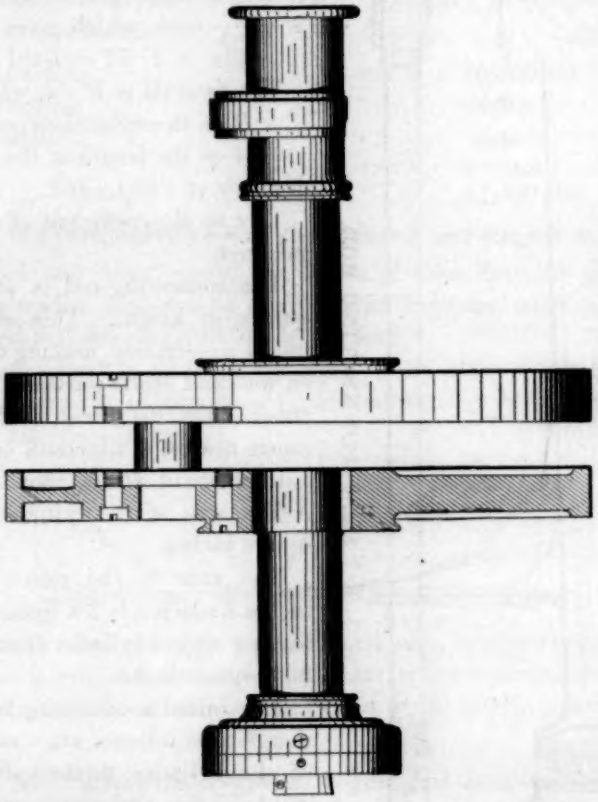


Fig. 2.—CRANK.

The weight of the reciprocating parts of this engine is as follows:

Piston, with rod, . . .	83 lbs.
Crosshead, . . .	42 "
Connecting-rod, . . .	109 "
Total, . . .	234 lbs.

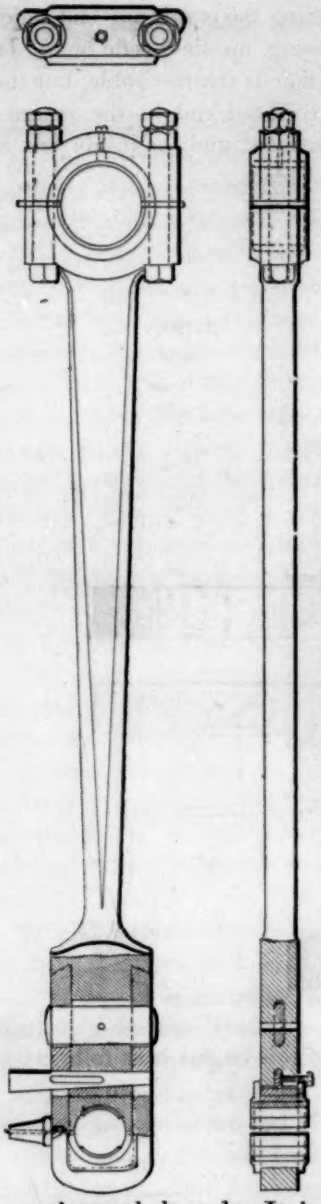


Fig. 3—CONNECTING ROD.

The initial acceleration of this mass, or the force required, on the dead centres, to give it the motion necessary to relieve the crank from strain, is as follows:

$350^2 \times \cdot66 \times \cdot000341 = 27\cdot57$,

or 27·57 times the weight of the mass, which gives

$234 \times 27\cdot57 = 6451$ lbs.

The formula is $R^2\, l\, c$, when

R = the revolutions per minute;

l = the length of the crank in decimals of a foot; and

c = the coefficient of centrifugal force.

The connecting-rod is 48″, or 6 cranks, in length. This affects the initial acceleration, making this to be on the dead centre farthest from the crank 7526 lbs., and on the dead centre nearest to the crank 5376 lbs., a difference of 40 per cent.

The area of the cylinder is 98·2 square inches.

The area of the piston rod, $1\frac{3}{4}$ inches diameter, is 2·4 square inches, leaving area of cylinder at crank end 95·8 square inches.

The initial accelerating forces are therefore as follows, viz.: at the end of the cylinder farthest from the crank 77 lbs., and at the end of the cylinder nearest to the crank 56 lbs., on the square inch of piston area.

The counterweight was after some trials fixed at 135 lbs. This leaves 99 lbs. of the reciprocating parts running unbalanced. It is found that this is not sufficient to disturb the stability of the engine, while on the other hand the counterweight

is not so great as to exert an objectionable strain in the vertical direction.

The total weight of the engine is 6445 lbs.

The engine and dynamo are mounted on a cast-iron base plate, made for convenience in two parts, and bolted together.

The dimensions of this base plate are as follows: length 14 feet, width 8 feet 9 inches; and its weight is 10,300 lbs. The entire weight is therefore as follows:

Base plate, . . .	10,300 lbs.
Dynamo, . . .	44,800 "
Engine, . . .	6,450 "
Total, . . .	61,550 lbs.

Fig. 4 is a perspective view of the Dynamo and Engine combined.

The last and most careful test of one of these dynamos gives the following results, as shown by the indicator diagrams, which are here reproduced full size; scale 80 lbs. to the inch.*

The lamps used in all the trials were of the older construction, of which 8½ lamps, at 16 candle power incandescence, require one horse-power of electrical energy.

Since these were placed for experimental uses, improvements in the lamp have increased their economy, so that one horse-power is sufficient to maintain fully 10 of the present lamps at 16 candle power incandescence.

Diagram No. 1 shows the friction of engine and dynamo at 350 revolutions per minute, requiring . . 13·63 HP

Diagram No. 2 shows the resistance with the magnet circuit on = ... 19·17 HP

Field 5·78 ohms, 103 volts.

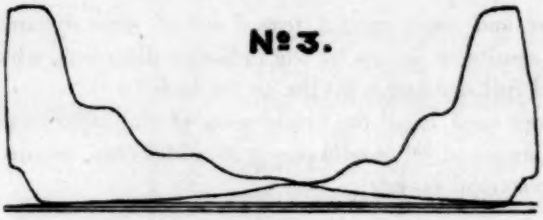
*As many persons might doubt about these diagrams having been really taken from any engine and by any indicator at this speed, we have examined the originals taken by a Tabor indicator, and can vouch for their accuracy.—Ed. J. F. I.

The increased resistance due to the magnets was . 5·54 HP

Of this, the calculated energy developed in the magnets was $\frac{103^2 \times 44{\cdot}3}{5{\cdot}78 \times 33{,}000} =$ . . . 2·46 HP

Leaving energy to be accounted for by local currents in iron core of armature, and in armature bars, . 3·08 HP

Diagram No. 3 shows the work done in maintaining 300 lamps.



These, in the ratio of $8\frac{1}{2}$ to 10, were equal to 353 lamps of the present construction. The pressure was maintained also at 102 volts, representing 25 candle power, in place of 98 volts, representing 16 candle power incandescence, which requires the number of lamps to be increased in the ratio of 102^2 to 98^2, or to 382 lamps.

The pressure at the armature was 104 volts, showing a loss in the conductor of 2 volts, which would increase the number of lamps as 104 : 102.*

The total correction is therefore as follows:

$$300 \times \frac{10}{8{\cdot}5} \times \frac{102^2}{98^2} \times \frac{104}{102} = 389 \text{ lamps.}$$

The power exerted was . . . 60·6 HP

which gives to the indicated horse-power

$$389 \div 60{\cdot}6 = 6{\cdot}42 \text{ lamps.}$$

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*The conductors were insufficient, occasioning a loss, that increased with the increase in the number of lamps.

The magnet circuit had now a resistance of 5·28 ohms with 104 volts pressure, representing

$$\frac{104^2 \times 44{\cdot}3}{5{\cdot}28 \times 33{,}000} = \quad . \quad 2{\cdot}75 \text{ HP}$$

Substituting this in place of 2·46 HP in the first trial, we have 19·46 HP, which, deducted from 60·6 HP, leaves net 41·14 HP.

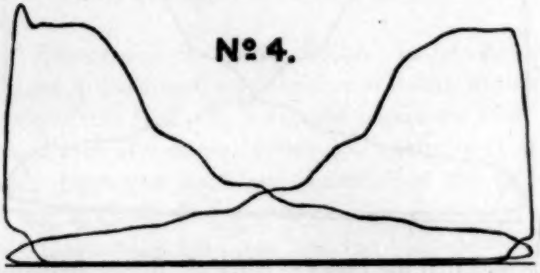
This gives 389 ÷ 41·14 = 9·45 lamps per HP.

Diagram No. 4 shows the work done in maintaining 700 lamps.

The pressure at the lamps was maintained, as in the preceding trial, at 102 volts, which required at the armature a pressure of 105 volts.

The total correction in this case is therefore

$$700 \times \frac{10}{8{\cdot}5} \times \frac{102^2}{98^2} \times \frac{105}{102} = 919 \text{ lamps.}$$



The power exerted was . . . 115·83 HP

giving to the indicated horse-power,

$$919 \div 115{\cdot}83 = 7{\cdot}93 \text{ lamps.}$$

The resistance of the magnet circuit was now 4·78 ohms, with 105 volts pressure, representing, $\frac{105^2 \times 44{\cdot}3}{4{\cdot}78 \times 33{,}000} = 3{\cdot}1$ HP.

Substituting this in place of 2·46 HP in the first trial, we have 19·81, which, deducted from 115·83 HP, leaves net 96·02 HP.

This gives 919 ÷ 96·02 = 9·57 lamps per HP.

Diagram No. 5 shows the work done in maintaining 1050 lamps.

The pressure at the lamps was maintained in this trial at only 99 volts, but this required at the armature a pressure of 108 volts, showing a loss of 9 volts in conduction.

The total correction in this case is thus

$$1050 \times \frac{10}{8{\cdot}5} \times \frac{99^2}{98^2} \times \frac{108}{99} = 1375 \text{ lamps.}$$

The power was . . . . 168·4 HP

giving to the indicated horse-power

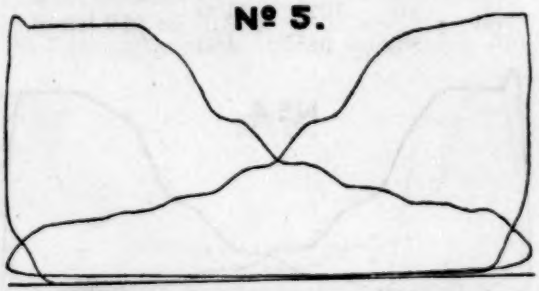
$$1375 \div 168{\cdot}4 = 8{\cdot}16 \text{ lamps.}$$

The resistance of the magnet circuit was now 3·28 ohms, with 108 volts pressure, representing

$$\frac{108^2 \times 44{\cdot}3}{3{\cdot}28 \times 33{,}000} = 4{\cdot}77 \text{ HP.}$$

Substituting this in place of 2·45 HP in the first trial, we have 21·48 HP, which, deducted from 168·4 HP, leaves net 146·92 HP.

This gives 1375 ÷ 146·92 = 9·36 lamps per HP.



It will be seen that the losses of efficiency due to undiscovered resistances are only

In the first case, . 10 — 9·45 = ·55 HP per lamp,
In the second case, . . 10 — 9·57 = ·43 HP per lamp, and
In the third place, . 10 — 9·36 = ·64 HP per lamp,

Averaging 5·4 per cent.

The friction in the journals of the armature, when driven in this manner, does not increase with the resistance, and, on account of the action of the reciprocating parts of the engine, that in its bearings is also nearly a constant quantity, whatever the load may be.

The above figures show this very clearly, the subtraction of the friction diagram in each case exhibiting substantially the same net power per lamp.

ON THE EFFICIENCIES OF THE STEAM BOILER AND ON THE CONDITIONS OF MAXIMUM ECONOMY.

By Robert H. Thurston.

[Presented to the American Society of Mechanical Engineers, Philadelphia Meeting, April, 1882.]

In the design and construction of a steam boiler, and in its operation, problems arise which must be solved, by the mechanical engineer, in their natural order before he can say with confidence that the best interests of the purchaser or proprietor of the apparatus are fully met in its construction and management. Such problems form the subject of this paper.

(*1.*) *The "Efficiency of the Steam Boiler"* is the ratio of the total quantity of heat utilized in the production of steam to that set free in the combustion of the fuel. It has as the maximum limit unity. It is a function of area of heating surface and quantity of fuel burned, and of factors dependent upon the character of the fuel and of its combustion, and upon the design of the boiler.

(*2.*) *The "Commercial Efficiency"* or the *"Efficiency of Capital"* employed in the maintenance of steam-generating apparatus of a given power is measured by the ratio of quantity of steam produced to the cost of its continuous production, *i. e.*, by the reciprocal of the total cost of steam per pound or per cubic foot at the required pressure. This efficiency is a maximum when that cost is a minimum.

(*3.*) *The Efficiency of a Given Boiler Plant,"* as the writer would call it, or the commercial efficiency of a steam boiler already in place and in operation, is still another quantity. It is a maximum when the work done by the boiler can be increased beyond that for which it was proportioned—if designed originally to give maximum efficiency of capital at a pre-arranged power, as above—until the amount of steam made by that boiler per dollar of working expense is made a maximum.

These three efficiencies differ essentially in their character, and are determined by different processes. In the first case, the engineer designing a boiler finds himself called upon to determine what is the maximum efficiency that it will be economical, or otherwise advisable,

to endeavor to secure, and then calculates the proportions necessary to secure that efficiency. Or, knowing the proportions of any boiler already designed and built, he may be required to calculate its probable efficiency and the quantity of fuel called for to make a certain quantity of steam, *i. e.*, to determine the steam generated per pound of coal burned.

In the second case, the designing engineer calculates the proportions of heating surface to grate surface or to fuel burned, where the quantity of steam required is known, and the conditions determining costs, which shall give that quantity of steam at least total running expense.

In the third case, the boiler is in place and in operation, and it is found that it is advisable to ascertain what quantity of steam can be made when its cost per unit of weight or of volume is a minimum.

In the first two cases, the variable element is usually the area of heating surface per pound of fuel burned in the unit of time; in the last, the variable is the quantity of fuel burned or of steam made.

(*4.*) *To What Capacity may any Given Boiler be Forced without Exceeding that Cost of Steam at which a Paying Profit is Given?* is another problem in steam boiler efficiency and one which is of more frequent occurrence, and is usually more important than the preceding.

The economical maximum of steam production is evidently determined by the money value, to the producer, of the steam made.

(*1.*) *Efficiency of the Steam Boiler.*

This case has been studied by Rankine, who deduces a very simple and handy formula for the efficiency of a boiler of known proportions, using a fuel of known calorific value.

Taking the rate of conduction of heating surfaces as varying as the square of the difference of temperatures of the gas and of the water on opposite sides of the sheet, the formula

$$E = \frac{1}{1 + \frac{ac'^2 W^2}{SH}}$$

is readily deduced, in which E is the efficiency, a a constant, c' the specific heat of the furnace gases, and W their weight; while H is the total heat expended and S the heating surface. This expression is further transformed into

$$E_1 = \frac{BE}{1 + \frac{AF}{S}}$$

in which E is the theoretical evaporative power of the fuel per pound, E_1 the probable actual evaporation in a boiler in which F is the weight of fuel burned on the unit of area of grate, and S is the area of heating surface per unit of the same area.

A and B are here coefficients, having values respectively of 0·3 to 0·5 and 0·9 to 1 for bituminous coals, according to Rankine, and from 0·3 to 0·5 and from 0·8 to 0·9 with anthracite coal, as determined by experiments made by the writer. The lower values of A are obtained when using a minimum air-supply and the value of that coefficient is seen, by comparing the two equations just given, to vary as the square of the quantity of air supplied to the fuel. The value of B is dependent upon the character of the boiler, being greater as the design and construction are improved.

The following are illustrations of the results thus obtained:

EFFICIENCY OF STEAM BOILERS.

	I.		II.		III.		IV.	
$\frac{F}{S}$	$A=0{\cdot}5$	$B=1$	$A=0{\cdot}3$	$B=1$	$A=0{\cdot}5$	$B=1$	$A=0{\cdot}3$	$B=1$
0·17	0·92		0·95		0·83		0·86	
0·33	0·87		0·91		0·78		0·82	
0·40	0·83		0·89		0·75		0·80	
0·50	0·80		0·87		0·72		0·78	
0·67	0·75		0·83		0·68		0·75	

EXPENSES OF OPERATION.

The expenses of operating a steam boiler may be classed under three heads:

(1.) Those costs of boiler and its maintenance which are dependent upon the size and the character of the boiler itself and its attachments, such as interest on cost of boiler and setting, rent of building and other items on construction account, such as taxes, insurance, repairs and depreciation, etc., etc.

(2.) Those costs of operation which are dependent upon the quantity of steam made and of fuel consumed, such as market price of fuel, cost of transportation, storage (an important item on shipboard especially), and of feeding into the furnace, cost of feed-water and its introduction into the boiler, and a certain part of other costs of attendance and supply.

(3.) In addition to these variable expenses are often, perhaps usually, to be counted certain constant expenses which are unaffected by any change of proportions of boiler likely to be made in the assumed case, such as nearly, or quite frequently all, the costs of attendance.

(2.) *Commercial Efficiency of the Boiler.*

A given amount of steam being demanded, it may be obtained from a small boiler using fuel extravagantly or from a large boiler using fuel economically. In each case arising in practice, there will be found a certain easily determined proportion of heating surface to grate surface and a definite size of boiler which will, on the whole, supply the desired quantity of steam most economically. Thus:

Let the total cost of fuel per annum and per pound burned per hour on the square foot of grate or on the square metre be called C. Let the total cost per annum of boiler, per square foot or per square metre of heating surface, be called D, and let $\frac{C}{D} = R$. In the first item is included all items of Class 1, and in the second all of Class 2.

Then the cost of boiler maintenance per annum is DSG, where S is the area of heating surface per unit of area of grate and G is the area of grate. The cost of fuel, etc., per annum, as per Class 2, is CFG, if F is the weight of fuel burned per unit of area of grate.

The total of costs variable with change of proportion of boiler is

$$P = DGS + CFG.$$

The profitable work of the boiler is measured by the quantity, by weight, of steam made, $FGE_1 = W$; E_1 being the evaporation of water per unit of weight of fuel.

The ratio of cost to work done is

$$y = \frac{P}{W} = \frac{DGS + CFG}{FGE_1} = \frac{CF + DS}{E_1 F}.$$

This quantity being made a minimum by variation of the area S, the most economical boiler is obtained.

But E_1 is a function of S and, taking the value of E_1 from the equation

$$E_1 = \frac{BE}{1 + \frac{AF}{S}},$$

we obtain

$$y = \frac{(DGS + CFG)\left(1 + \frac{AF}{S}\right)}{BEFG} = \frac{DGS + ADFG + CFG + \frac{ACF^2G}{S}}{BEFG}$$

$$= \frac{DS + ADF + CF + \frac{ACF^2}{S}}{BEF}$$

which is a minimum when

$$S = F\sqrt{\frac{AC}{D}} = F\sqrt{AR}; \quad \frac{S}{F} = \sqrt{AR}.$$

In illustration: Let a boiler, set in place, complete with all its appurtenances and in running order, cost $3 per square foot of heating surface, and the annual charges on all accounts entered in Class 1, above, be 20 per cent. on this cost, the annual charge becomes $DS = \$0.60 \times S$ per square foot of grate, *i. e.*, $D = \$0.60$. Let the cost of operation, as for Class 2, amount to $15 per annum per pound of fuel burned per hour on the square foot of grate; then $CF = \$15$; $C = \$15$; $\frac{C}{D} = R = 25$.

Assume $F = 10$ pounds of fuel per hour per square foot of grate, $A = 0{\cdot}5$.

For this case, then, the boiler should have per square foot of grate

$$S = F\sqrt{AR} = 10 \times (0{\cdot}5 \times 25)^{\frac{1}{2}} = 35;$$

35 square feet of heating surface.

Similarly we get the following values:

COMMERCIAL EFFICIENCY OF BOILERS.

Ratio of Areas of Heating and Grate Surfaces.

Values of *S*.

F	6	10	12	15	20	30	40	50
R								
25	21	35	42	52	70	105	140	175
16	17	28	34	42	56	84	112	140
9	12	21	24	32	42	63	84	105
4	8	14	16	21	28	42	56	70

These values are 20 or 25 per cent. lower for forced draught.

Where the boiler is worked almost continuously, as in flour mills and some other establishments kept in operation night and day throughout the year, the higher values will be found correct; when the boiler is worked discontinuously or, as in steam fire engines and some classes of steam vessels, a comparatively small proportion of the annual working time of the establishment or whole plant, the values of S become very small.

It is seen that the best area of heating surface will vary nearly as the square root of the total working time per annum. Boilers worked continuously, worked twelve hours out of the twenty-four, or eight honrs in the day, will require, respectively, values of S having the proportion 1, 0·7 and 0·6 nearly.

The total required area of grate is $\frac{W}{E_1 F} = G$; the total area of heating surface is $\frac{WS}{FE_1} = SG = \frac{W(S+AF)}{BEF}$.

The following are examples, in greater detail, of the application of the above:

EXPENSE ON BOILER ACCOUNT AND MAXIMUM COMMERCIAL EFFICIENCY.

Cases.	*Stationary.*		*Marine.*	
	I.	II.	III.	IV.
Class 1 (D).	Cornish.	Tubular.	Tubular.	Tubular.
Total annual cost of boiler per unit of S,	$1.50	$2.00	$3.00	$2.00
Interest,	.09	.12	.15	.12
Repairs and depreciation,	.15	.20	.45	.30
Rent, insurance and miscellaneous,	.10	.07	1.00	.20
Total value of D,	.34	.38	1.60	.62
Class 2 (C).				
Fuel (@ $5 for I, II, IV; $4 for III) per unit of F,	7.50	7.20	12.00	2.00
Transportation and storage,	1.00	1 00	10.00	1.00
Attendance (variable cost),	0.00	0.50	0.50	0.00
Total,	8.50	9.00	22.50	3.00

Value of $\frac{C}{D} = R$, . .	25	23	14	5
Value of A, . . .	0.5	0.3	0.3	0.5
Value of $\sqrt{AR}$ . .	3.5	2.7	2.0	1.6
Value of F, . . .	8	10	16	20
Value of $\sqrt{AR} = S$, .	28	27	32	32

R varies in magnitude very greatly in practice, falling as low as 4 and rising as high as 50 with varying cost of fuel and length of working time.

The engineer thus solves the most important problem in boiler-design which may be thus enunciated: To determine the commercial efficiency of a steam boiler doing a fixed amount of work; or, given all variable expenses of boiler installation, maintenance and operation, to determine what proportion of heating surface to grate surface or fuel burned will give the required amount of power at least total cost.

(3.) *Commercial Efficiency of a Given Boiler.*

A second commercial problem may sometimes be presented to the engineer: A steam boiler is in place and in operation; all constant expenses are known and all variable costs of maintenance and operation are determinable. The question arises, or may arise whenever additional steam is called for: How much can be obtained from the apparatus when driven to such an extent as to yield most steam per dollar of total cost of operation? The independent variable is now the quantity of fuel burned in the boiler, and this is, in the established equation, represented by F, the fuel burned per unit of area of grate. This problem is thus stated:

Given: All expenses, constant and variable, and the method of variation of the latter and the proportions of the boiler as actually constructed, to determine that rate of combustion which will make the Commercial Efficiency of the Given Plant a maximum.

For this case, let K represent that total annual expense of working which is independent of Classes (1) and (2) and which falls into Class (3) and let $k = \frac{K}{G}$.

Let all other symbols stand as before.

Then the total cost of maintenance and operation will be

$$P' = kG + DGS + CFG,$$

while the work done will be, as before,

$$W = FGE_1.$$

The quantity to be made a minimum is, for the present case, the quotient of P' by W,

$$y = \frac{P'}{W} = \frac{k + DS + CF}{E_1 F},$$

F being taken as the independent variable.

This becomes a minimum when we substitute for E_1 its value $E_1 = \frac{BE}{1 + \frac{AF}{S}}$ and make the first derivative equal zero.

Then we find

$$F_1 = \sqrt{\frac{kS + DS^2}{AC}}$$

When, in this expression for the value of F, giving maximum weight of steam for the dollar expended, we make $k = 0$, the expression may be reduced, as obviously should be possible, to the form shown already to be that giving the solution of the first problem:

$$S = F_1 \sqrt{AR}.$$

The following cases illustrate this problem:

EXPENSES OF BOILER AND MAXIMUM ECONOMY OF PLANT.

Cases.		*Stationary.*		*Marine.*	
		I.	II.	III.	IV.
Cost of maintenance:	D,	\$0.34	\$0.58	\$0.88	\$0.62
Cost of operation:	C,	8·20	9.00	14.50	3.00
Cost of operation:	K,	30.00	25.00	10.50	10.00
For maximum fuel and work:	F_1,	16	13	17	21
For maximum efficiency, as before:	F,	8	10	16	20

Case No. 1 is that of a Cornish boiler, No. 2 that of a multitubular stationary boiler, No. 3 that of a sea-going steamer and No. 4 that of a yacht.

It is seen that in all cases the weight of steam delivered from the boiler and the quantity of fuel burned at maximum commercial efficiency, for the case assumed, are less than where the boiler—once set and still capable of being forced to deliver more steam than originally

proposed and calculated upon—is worked up to a maximum delivery per dollar of total expense.

"Maximum Commercial Efficiency of Boiler" and "Maximum Efficiency of a Given Plant" are therefore by no means identical conditions, and it will usually be found that when this maximum work can be put on the boiler, it might be done still more economically by a boiler specially designed, as in the first problem, to do the increased quantity of work; the conclusions from this fact being simply that economy dictates that as much steam power as possible should be grouped into a single plant in order to diminish the proportional cost of the constant part of running expenses, *i. e.*, otherwise stated, there being given a certain necessary expenditure, invariable within certain limits with variation of size of boiler or of quantity of steam made, the larger the amount of work done without increasing this constant expense, the cheaper will the steam be made.

The larger the plant supervised by the engineer the less the total cost per pound of steam made, other conditions of economy being unchanged.

NOTE ON THE ECONOMY OF THE WINDMILL AS A PRIME MOVER.

By Alfred R. Wolff, M.E.

[A paper read before the American Society of Mechanical Engineers, April 21, 1882.]

In the course of professional work I have repeatedly had occasion to investigate the question of the impulse of wind upon windmills, and to observe the economical performance of the latter. From time to time I have published various results of these investigations, but have not given a record of the actual economy of the windmill, the subject-proper of this note. Before, however, setting forth the special economy in the use of the windmill as a prime-mover for small powers, it is well to refer briefly to some publications which may be of interest in connection with the general subject.

For the early history of windmills and a description of European windmills, Fairbairn's "Mills and Millwork" may be consulted to advantage. For a description of the details of American windmills see article on Windmills in Appleton's Cyclopedia of Mechanics, 1880. For an account of experiments on windmills see Smeaton's "Miscel-

laneous Papers," and Coulomb's "Théorie des Machines Simples." For the best angles of impulse and "weather" for windmill blades see *Engineering and Mining Journal*, October 7, 1876, and Appendix I, of this note. The question of the impulse of wind upon windmill blades involves too the consideration of the relation between the velocity and pressure of the wind. A concise summary of this question, useful to no small extent in its reference to the journals containing the original publications of those who have given the subject attention, will be found in a paper by Mr. F. Collingwood, C.E., read before the American Society of Civil Engineers, April 6, 1881, on "An Examination into the Method of Determining Wind Pressures." In Appendix II of this note will be found the tabulated result of the writer's own work in this connection, in which the effect of temperature has received its due consideration. In the *Journal of the Scottish Meteorological Society*, 1880, Mr. F. Stevenson describes some interesting experiments, tending to show the effect of the height of observation above the ground on the relative velocity and pressure of wind. (See also *Engineering*, January 14, 1881.)

Having thus indicated some of the publications, where can be studied those considerations which affect the construction of windmills and which to some extent determine as well its efficiency, I propose now to direct attention to the demonstration of the fact that whatever improvement in efficiency be possible in the future, windmills, as at present constructed, are the most economical prime-movers for those uses for which they are specifically designed.

Designation of mill.	Velocity of wind in miles per hour.	Revolution of wheel.	Gallons of water raised per minute to an elevation of						Equivalent actual useful horse-power developed.	Average number of hours per day during which this result will be obtained.
			25 feet.	50 feet.	75 feet.	100 feet.	150 feet.	200 feet.		
8½ ft. wheel.	15 to 20	70 to 75	6·162	3·016	.....	....	.....	.....	·04	8 to 10
10 ft. wheel.	15 to 20	60 to 65	19·179	9·563	6·638	4·750	.....	....	·12	8 to 10
12 ft. wheel.	15 to 20	55 to 60	33·941	17·952	11·851	8·485	5·680	.....	·21	8 to 10
14 ft. wheel.	15 to 20	50 to 55	45·139	22·569	15·304	11·246	7·807	4·998	·28	8 to 10
16 ft. wheel.	15 to 20	45 to 50	64·600	31·651	19·542	16·150	9·771	8·075	·41	8 to 10
18 ft. wheel.	15 to 20	40 to 45	97·682	52·165	32·513	24·421	17·485	12·211	·61	8 to 10
20 ft. wheel.	15 to 20	35 to 40	124·950	63·750	40·800	31·248	19·284	15·938	·78	8 to 10
25 ft. wheel.	15 to 20	30 to 35	212·381	106·964	71·604	49·725	37·349	26·741	1·34	8 to 10

In this demonstration, conclusions will be based only on observed facts, or actual running results. I am enabled to do this, inasmuch as

some five years ago, one of the most prominent windmill manufacturers came to me with a few scattered data of actual performances of his mills, which, however, were sufficient by means of deductions and analogy, from theoretical principles, to warrant the preparation of the preceding table.

Since the preparation of this table over a thousand windmills have been sold on its guarantee, and in all cases the actual results obtained, both in this country and elsewhere, did not vary sufficiently from those above presented to cause any complaint whatever; a proof that the results as tabulated are very close or certainly not too high. If it be claimed that the horse-power developed appears small, from the standpoint of a (false) prevalent popular opinion, it should be observed in response that the actual results noted in the table are in close agreement with those obtained by theoretical analysis of the impulse of wind upon windmill blades. The manufacturer's own observations during the past five years have led him to conclude that they are correct. It will therefore be just to base the economy of the windmill as prime-mover on the performances recorded in this table, and the expense of obtaining the power will be presented further on.

Conceding for a moment its economy, the possible employment of the windmill as prime-mover is dependent as well on other considerations. The objection urged against the use of windmills is the uncertainty of the motive fluid—wind; but we will see that this objection serves not to prevent, but only to restrict the use of the windmill as prime-mover. Of course it must be acknowledged that there are minutes and hours of total calm, and this restricts the employment of the windmill for such purposes, where either the nature of the work done by the windmill allows of its being suspended during a calm, as work on a farm for instance, or where the work can be stored, as in pumping water for a variety of purposes, or in compressing air, or, as was lately proposed by Sir William Thomson,* for storing electricity by means of dynamo machines and electrical accumulators. There is another restriction which goes into practical effect, namely, that the large size of a windmill for a given power makes it practically desirable only to be used for small powers. But actually it is only designed

* Presidential address "On the Sources of Energy in Nature Available to Man for the Production of Mechanical Effect," delivered before Section A, of the British Association for the Advancement of Science, 1881.

for the use of small powers, usually between $\frac{1}{25}$ and 4-horse power,* and for such powers it will be shown in this note that it is the most economical and serviceable prime-mover for the purposes for which it is designed.

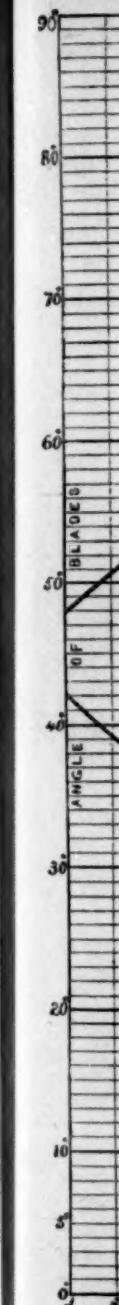
The difficulty urged by Sir William Thomson to its adoption, in its present state of development for storing electrical accumulators, is the *first cost* of the windmill, but this was doubtless an oversight,† for the *interest* on the capital expended and not capital itself becomes one of the items of current expense in judging of the economy of prime-movers, and, as will become evident from the contents of this note the question of expense of producing power will not prove an objection, but on the contrary the best reason for the introduction of windmills to charge electrical accumulators.

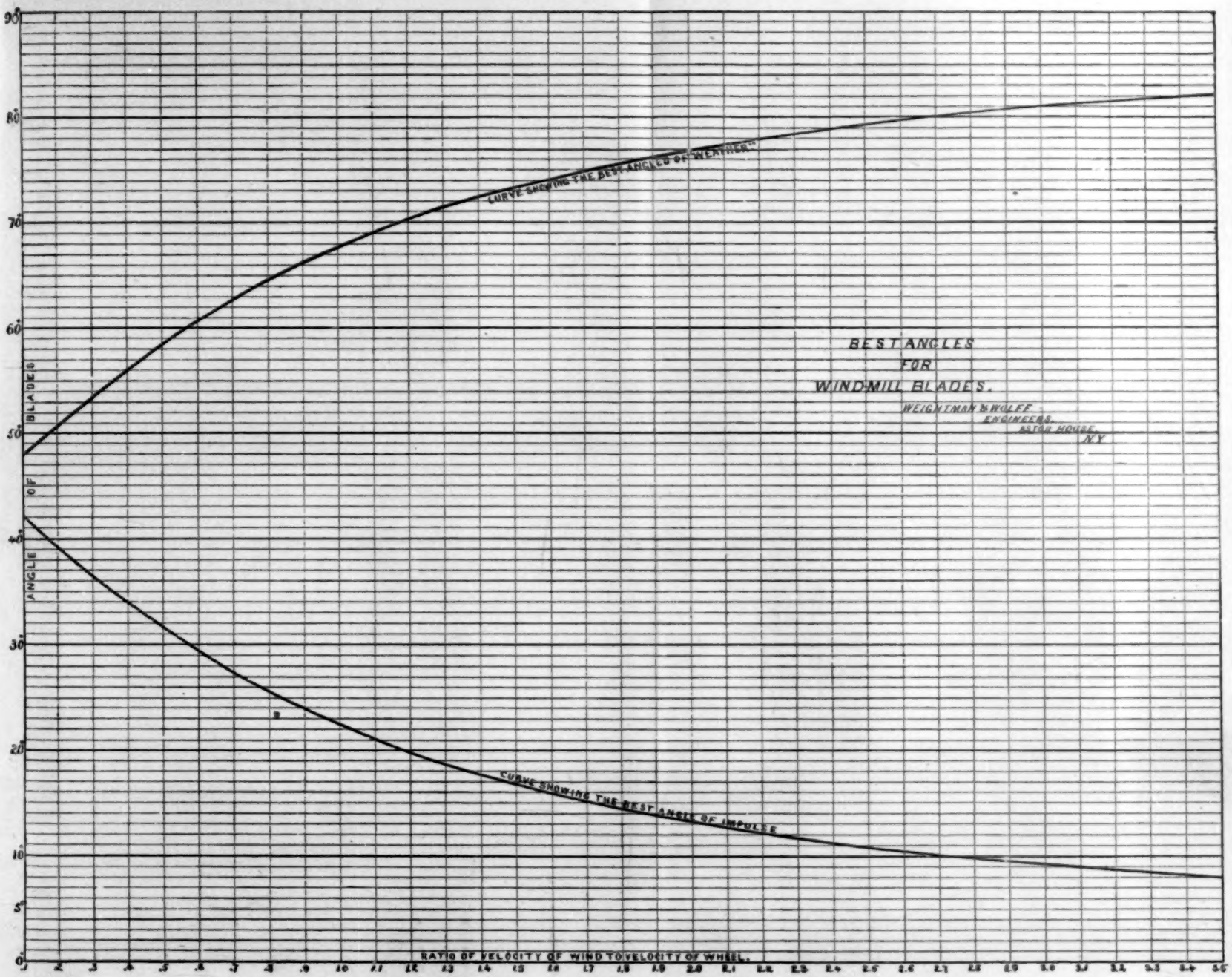
It must be specially mentioned that experience has shown that the wind blows fast enough to run the windmill up to the regulating speed in the above table on an average of eight to ten hours per day of twenty-four hours, and our estimate of work done and expense of power will be based on an actual running of only eight hours per day.

The current expense of any prime-mover, or the cost of obtaining the horse-power developed per unit of time, which alone should form the basis of a comparison of the economy of different prime-movers, consists principally of interest, repairs, and depreciation of plant, cost of fuel, oil and attendance. In windmills the cost of fuel is zero, wind being a free gift of nature. The attendance required for the self-regulating windmills designated in the above table amounts only to filling the oil cups three or four times a month, the work of a few minutes, which any one can attend to. If any account is to be taken of this service, an allowance of fifteen cents a month would really be quite extravagant. In the following table such allowance has been

* Coulomb, in his experiments with a windmill of four sails, 70 feet in diameter, breadth of sails 6⅔ feet, the wind blowing at a velocity of fifteen miles per hour, obtained an actual useful result equivalent to about 7 horse-power.

† In the same paper Sir William Thomson, in estimating the cost of utilizing the power of the Niagara Falls for electric lighting correctly considers the interest on first cost in determining the economical aspect of the question. The oversight noted in the text becomes important and worthy of mention only, inasmuch as any statement of so distinguished and justly esteemed authority as Sir William Thomson is apt to be accepted on the basis of authority alone—and it must be added that the great caution usually displayed by the most eminent living English physicist entitles him *prima facie* to this mark of consideration.




BEST ANGLES
FOR
WINDMILL BLADES.
WEIGHTMAN & WOLFF
ENGINEERS.
ASTOR HOUSE.
NY
CURVE SHOWING THE BEST ANGLES OF "WEATHER"
CURVE SHOWING THE BEST ANGLE OF IMPULSE
ANGLE OF BLADES
RATIO OF VELOCITY OF WIND TO VELOCITY OF WHEEL.
90°
80°
70°
60°
50°
40°
30°
20°
10°
5°
0°

made. Experience has shown that the repairs and depreciation items jointly are amply covered by five per cent. of the first cost per annum. Interest is calculated at five per cent. per annum. The oil used is a very small quantity—a few gallons per year—and is allowed for in the table according to the size of mill. All the items of expense, including both the interest and repairs, are reduced to the hour by dividing the costs per annum by $365 \times 8 = 2920$, the interest, etc., for the twenty-four hours being charged on the eight hours of actual work. By multiplying the figures in column 5 by $\frac{365 \times 8}{100 \times \cdot 05} = 584$ the first cost of the windmill in dollars is obtained.

TABLE SHOWING ECONOMY OF THE WINDMILL.

1	2	3	4	5	6	7	8	9	10
Designation of mill.	Gallons of water raised twenty-five feet per hour.	Average number of hours per day during which this quantity will be raised.	Equivalent actual useful horse-power developed.	Expense of actual useful power developed in cents per hour.					Expense per horse-power in cents per hour.
				For interest on first cost. (First cost, including cost of windmill, pump, and tower, five per cent. per annum.)	For repairs and depreciation. (Five per cent. of first cost per annum.)	For attendance.	For oil.	Total.	
8½ ft. wheel.	870	8	·04	0·25	0·25	0·06	0·04	0·60	15·0
10 ft. wheel.	1,151	8	·12	0·30	0·30	0·06	0·04	0·70	5·8
12 ft. wheel.	2,036	8	·21	0·36	0·36	0·06	0·04	0·82	3·9
14 ft. wheel.	2,708	8	·28	0·75	0·75	0·06	0·07	1·63	5·8
16 ft. wheel.	3,876	8	·41	1·15	1·15	0·06	0·07	2·43	5·9
18 ft. wheel.	5,861	8	·61	1·35	1·35	0·06	0·07	2·83	4·6
20 ft. wheel.	7,497	8	·79	1·70	1·70	0·06	0·10	3·56	4·5
25 ft. wheel.	12,743	8	1·13	2·05	2·05	0·06	0·10	4·26	3·2

The number of gallons pumped by the thirty foot and thirty-five foot mills and larger sizes, and the economy of the same are not given in the above table, for the number of larger mills in operation is not sufficient to insure the authenticity of the results thus far obtained. The performance of the thirty foot mill, as far as observed, seems to gravitate to a pumping capacity equivalent to 2·4 horse-power, and an expense of 2·5 cents per horse-power per hour.

When the figures in the table are contrasted with the cost of pumping the same amount of water by other prime-movers, where in addition to expense of interest, repairs, depreciation and oil, there are the greater expenses of fuel and attendance, and often extra insurance

on property owing to the use of steam, the economy of the windmill must be evident to all.

To recapitulate: The figures given in the body of this note are the results of actual experience with hundreds of windmills, and as such, it was believed, would not be without interest. They prove conclusively that at the present time windmills are the most economical prime-movers for the powers and purposes outlined in this note, and for which they are usually designed.

Appendix I.

In a "Dissertation on the Theory and Practice of Windmills," published in the *Engineering and Mining Journal*, October 7, 1876, the writer developed the formula:

$$\tan a = \frac{v}{c} + \sqrt{1 + \left(\frac{v}{c}\right)^2}$$

from which the best angle of impulse might be ascertained.

In this formula

a represents the angle of impulse of the wind upon the windmill blade (or sail), at any point of the blade, for maximum effect.

v = the velocity of the blade (at such point) in feet per second.

c = the velocity of the wind in feet per second.

The accompanying diagram is the graphical interpretation of that formula; the curves showing the best angles of impulse and "weather." The angle of "weather" is the complement of the angle of impulse, and is the angle which an element of the blade or sail makes with its plane of motion. Since there is no difference of effect between that caused by the blades moving against the air, and that caused by the air (or wind) striking upon the blades (assuming the same velocity in both cases), the angles given in the diagram will be found to be those of maximum efficiency for ventilating purposes as well as for windmills.

In the above diagram, the ordinates represent the best angles of weather and impulse expressed in degrees, and the abscissas the ratio of the velocity of the wind to the velocity of the windmill blades. Thus assuming the velocity of the wind to be 31·416 feet per second, the diameter of the wheel to be 35 feet, and the number of revolutions per minute to be made to equal 30, the velocity of the wind-wheel at a point $2\frac{1}{2}$ feet from the centre, of the shaft will be 7·854 feet per second; at five feet from the centre 15·708; at $7\frac{1}{2}$ feet, 23·562, etc.,

and the ratio of the velocity of the wind to the velocity of the sail $\frac{v}{c}$ will at $2\frac{1}{2}$ feet from centre of shaft equal .25; at 5 feet., .50; at $7\frac{1}{2}$ feet, .75, etc. The best angle of weather equals therefore at a distance $2\frac{1}{2}$ feet from the centre of the shaft, 38°; at 5 feet from the centre 32°; at $7\frac{1}{2}$ feet 27°, etc.; and the best angle of impulse equals at a distance of $2\frac{1}{2}$ feet from the centre of the shaft 52°; at 5 feet from the centre 58°; at $7\frac{1}{2}$ feet 63°, etc.

Appendix II.

Table Showing Relation Between Velocity and Pressure of Wind.

Velocity of Wind.		Pressure of wind in pounds per square foot of plane surface, perpendicular to its course, when $P = 2116{\cdot}5$ and temperature of wind =					
Miles per hour.	Feet per second.	0° F.	20° F.	40° F.	60° F.	80° F.	100° F.
1	1·46⅔	·005371	·005147	·004940	·004750	·004574	·004410
2	2·93⅓	·021482	·020586	·019761	·019001	·018294	·017641
3	4·40	·048335	·046318	·044465	·042751	·041166	·039694
4	5·86⅔	·085930	·082345	·079048	·076008	·073185	·070568
5	7·33⅓	·134271	·128668	·123514	·118758	·114355	·110267
6	8·80	·193354	·185287	·177867	·171017	·164675	·158784
7	10·26⅔	·263186	·252205	·242112	·232780	·224148	·216140
8	11·73⅓	·343767	·329423	·316228	·304050	·292774	·282265
9	13·20	·436283	·416945	·400243	·384828	·370555	·357305
10	14·66⅔	·537188	·514772	·494151	·475121	·457498	·441195
11	16·13⅓	·650036	·622908	·597955	·584923	·553600	·533815
12	17·60	·773645	·741357	·711656	·684244	·658865	·635301
13	19·06⅔	·908020	·870122	·835260	·803085	·773296	·745638
14	20·53⅓	1·053168	1·010206	·968770	·931449	·896879	·864814
15	22·00	1·209087	1·158616	1·112190	1·069347	1·029670	·992841
16	23·46⅔	1·375798	1·318354	1·265523	1·216763	1·171621	1·129707
17	24·93⅓	1·553273	1·488425	1·428786	1·373721	1·322751	1·275429
18	26·40	1·741556	1·668839	1·501951	1·540180	1·483006	1·429470
19	27·86⅔	1·940634	1·859598	1·785056	1·716260	1·652571	1·593439
20	29·33⅓	2·150516	2·060705	1·978095	1·901853	1·831270	1·765740
25	36·66⅔	3·362250	3·221749	3·092521	2·973261	2·862857	2·760359
30	44·00	4·845284	4·642062	4·456311	4·284344	4·125157	3·979371
35	51·33⅓	6·600829	6·324565	6·070498	5·836055	5·619046	5·417590
40	58·66⅔	8·630351	8·268791	7·936307	7·627948	7·345581	7·082012
45	66·00	10·935522	10·476877	10·055155	9·666070	9·305975	9·971746
50	73·33⅓	13·518265	12·950585	12·428068	11·947178	11·501614	11·088085
60	88·00	19·525304	18·702993	17·947145	17·250017	16·609025	16·006591
80	117·33⅓	34·981530	33·497300	32·133920	30·877150	29·715020	28·863716

In obtaining the above data attention was paid to the facts that the pressure depends upon both the velocity and the density of the air, and that this density depends upon the temperature, the barometric pressure, and the pressure due to the motion of the air. This table is for the average height of the barometer ($P = 2116{\cdot}5$ pounds per square foot), and for any other barometric pressure the figures in the

table must simply be multiplied by the ratio of the said barometric pressure reduced to its value for temperature of air of 32° F. to 2116·5. Thus letting p_3 = barometric pressure at any absolute temperature t, then $p = \frac{p_3 \times t}{491{\cdot}4}$, and the figures in the table corresponding to wind pressure must be multiplied by $\frac{p}{2116{\cdot}5}$.

For details of the method by which the above table of pressures is obtained, see *Engineering and Mining Journal*, September 23, 1876.

HARMONIC INTONATION OF CHIME BELLS.

By John W. Nystrom.

(Continued from page 432, vol. lxxxiii.)

When all the bells in a peal are made of one standard proportion, and cast of the same kind of metal, the diameter of each bell should be in proportion inversely as the number of vibrations per second of the note to be sounded. This rule holds good for any form of bells, and for any system of intonation.

The following table gives the proportionate number of vibrations of each note in one chromatic octave, and the corresponding proportionate diameter of each bell, according to French harmonic intonation, published in Roret's Encyclopedia, Paris, 1854, which is somewhat different from the German intonation.

In bell chimes the smallest bell is called the *triple*, and the largest the *tenor*, and assuming the diameter of the triple C to be the unit, then the diameter of the tenor will be C = 2, or double that of the triple, when the two bells sound an octave. The diameter of the intermediate bells should be in proportion, as noted in column *fraction* in the table, namely B = $\frac{10}{9}$, A = $\frac{6}{5}$ and F = $\frac{3}{2}$ of the diameter of the triple.

It is not necessary that the tenor or triple should sound the note C, but when they are an octave one must be double the diameter of the other, independent of the keynote, and the diameters of the intermediate bells should be in proportion, as shown in the table.

Harmonic Intonation of Chime Bells.

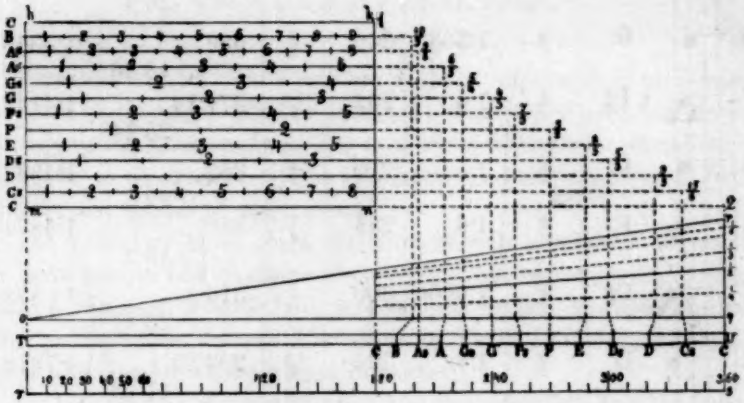
Keynote.		Diameters of Bells.			Vibrations.		Tempered Diameters.
		Fract.	Decimals.	Scale.	Fract.	Actual. Diff.	
13	C	1	1·000	180	2	528	1·0000
						52·8	
12	B	$\frac{10}{9}$	1·1111	200	$\frac{9}{8}$	475·2	1·0595
						5·43	
11	A♯	$\frac{9}{8}$	1·125	202·5	$\frac{16}{9}$	469·77	1·1225
						29·77	
10	A	$\frac{6}{5}$	1·2	216	$\frac{5}{3}$	440	1·1892
						17·6	
9	G♯	$\frac{5}{4}$	1·25	225	$\frac{8}{5}$	422·4	1·2599
						26·4	
8	G	$\frac{4}{3}$	1·3333	240	$\frac{3}{2}$	396	1·3348
						18·86	
7	F♯	$\frac{7}{5}$	1·4	252	$\frac{10}{7}$	377·14	1·4142
						25·14	
6	F	$\frac{3}{2}$	1·5	270	$\frac{4}{3}$	352	1·4983
						22	
5	E	$\frac{8}{5}$	1·6	288	$\frac{5}{4}$	330	1·5874
						13·2	
4	D♯	$\frac{5}{3}$	1·6666	300	$\frac{6}{5}$	316·8	1·6818
						23·47	
3	D	$\frac{2}{5}$	1·8	324	$\frac{10}{9}$	293·33	1·7818
						11·73	
2	C♯	$\frac{15}{8}$	1·875	337·5	$\frac{16}{15}$	281·6	1·8878
						17·6	
1	C	2	2·	360	1	264	2·0000
						26·4	

Bell founders have a scale called the *Bell scale*, which they generally keep in great secret, and by which the diameters of chime bells are determined geometrically, without any arithmetical calculation. The *bell scale* should he laid out on a wooden rod a little longer

than the diameter of the tenor, 2 to 2½ inches wide by 1 inch thick. For a peal of eight bells it is not necessary to draw the lines for the half notes.

The construction of this *bell scale* is represented by the accompanying illustration, namely, as follows:

The line *h*, *k* represents the diameter of the smallest or triple bell, or the unit for the measurements. Draw the perpendiculars *h*, *n* and *k*, *n*, and divide them into twelve equal parts; through each part draw the parallel lines extended beyond the line *k*, *n*, as represented by the dotted lines. There will then be thirteen parallel lines corresponding with the thirteen notes in the chromatic octave, as marked at the line *h*, *m*. From the table we find that the diameter of the bell B should be ten-ninths of that of the triple, C; therefore, divide the line B into nine equal parts, and prolong it one part outside of *k*, *n*, making ten ninth parts, the diameter required for the bell B.



The diameter of the bell A♯ should be nine-eighths of that of the triple C; therefore, divide the line A♯ into eight equal parts and add one part, making nine-eighths, the diameter required for the bell A♯.

The diameter of each bell is obtained in the same way, by dividing the corresponding line into as many parts as the denominator in the table, and add the difference of the numerator.

The diameter of the bell E should be eight-fifths of that of the triple C; then divide the line E into five equal parts and add 8—5= 3 parts, which makes the required diameter eight-fifths.

The diameter of the tenor C should be double that of the triple, which is obtained by setting off *m*, *n*, to 2

From the end of each diameter draw the dotted lines through the triangular scale *o*, *p*, *q*, which represents the thickness of the sound bow of each bell.

The scale *T U* is added by the writer to show the corresponding diameter of the bells for tempered intonation, and which scale is laid out from the last column in the table. The slanting dotted lines between *o*, *q* and *T U* shows the difference between the two methods of intonation. It will be observed that by the harmonic intonation there is very little difference between the bells B and A♯, whilst by the tempered intonation the difference between the diameters, and consequently also between the keynotes, increases in a regular order.

The French bell founders divide the diameter of the tenor into 360 equal parts, of which the diameter of the triple will be 180, and that of the intermediate bells as shown in column *Scale* in the table.

The most sensitive musical ears are freaks of nature, which can never be attained by culture, and the writer does not claim to be gifted with that accomplishment, but thinks that he has sufficient ear for music to perceive that the distance between B and C, as given by the German harmonic intonation, is too large, and that of the French is decidedly wrong. The French harmonic intonation, as given in Roret's Encyclopedia, gives two different values of B, of which one is too low, and the other is like the Stuttgart B.

There are many passages in music, and even in playing the diatonic scale, which evince that the distance between B and C should be half a note for melody. It must be admitted, however, that if B is made higher it will not chord so well with G, but the tempered intonation divides the difference.

The publication of this *bell scale* exposes and records in American literature a secret which is not worth keeping; for a peal of bells made by that scale can never ring good music, not only for the awkward intonation, but principally for the impossibility of properly regulating the *timbre* in the peal by that method. This *bell scale* is, however, published in Roret's Encyclopedia of Founding, Paris, 1854, but nothing is said there about graduating *timbre*, which is of the most importance in bell-ringing.

The harmonic properties of this scale can be easily analyzed by dividing the vibrations of each first note into that of the third or fifth,

in simple chords of two notes. Take, for instance, the simple chords of the *first* and major *third*, and place the major *third* in the numerator and the *first* in the denominator, as follows:

$$\frac{E}{C} = 1{\cdot}25. \quad \frac{F}{C\sharp} = 1{\cdot}25. \quad \frac{F\sharp}{D} = 1{\cdot}2857. \quad \frac{G}{D\sharp} = 1{\cdot}2.$$

$$\frac{G\sharp}{E} = 1{\cdot}28. \quad \frac{A}{F} = 1{\cdot}25. \quad \frac{A\sharp}{F\sharp} = 1{\cdot}2444. \quad \frac{B}{G} = 1{\cdot}2.$$

$$\left(\frac{B}{G} = 1{\cdot}25.\right) \quad \frac{C}{G\sharp} = 1{\cdot}25. \quad \frac{c\sharp}{A} = 1{\cdot}28. \quad \frac{d}{A\sharp} = 1{\cdot}25.$$

$$\frac{d\sharp}{B} = 1{\cdot}3333. \quad \frac{e}{C} = 1{\cdot}25.$$

When the proportion of vibrations of the *first* and major *third* is as 4 to 5, then the chord is harmonic and gives the number 1·25. In the above there are six harmonic and seven inharmonic chords.

The chord within the parenthesis is the Stuttgart intonation of B, which is also noted in Roret's Encyclopedia, but not adopted on the bell scale.

For the tempered intonation all the chords of the *first* and major *third* give the constant number 1·259.

The chords of the *first* and minor *third* are as follows:

$$\frac{E\flat}{C} = 1{\cdot}2. \quad \frac{E}{C\sharp} = 1{\cdot}172. \quad \frac{F}{D} = 1{\cdot}2. \quad \frac{F\sharp}{D\sharp} = 1{\cdot}1904.$$

$$\frac{G}{E} = 1{\cdot}03. \quad \frac{A\flat}{F} = 1{\cdot}2. \quad \frac{A}{F\sharp} = 1{\cdot}1666. \quad \frac{A\sharp}{G} = 1{\cdot}185.$$

$$\frac{B}{G\sharp} = 1{\cdot}125. \quad \frac{c}{A} = 1{\cdot}2. \quad \frac{c\sharp}{A\sharp} = 1{\cdot}2. \quad \frac{d}{B} = 1{\cdot}234.$$

$$\frac{c\flat}{C} = 1{\cdot}2.$$

For the tempered intonation all these minor chords give the constant number 1·1854.

Six of the above minor chords give 1·2, which is equal to that of two major chords. This, I think, is a positive proof of the incorrectness of the so-called *harmonic* intonation of the chromatic scale, and which, no doubt, is the cause of discordant bell ringing.

No intonation of the musical scale can accommodate equally well both melody and harmony, but the tempered intonation is best for melody and nearest right for harmony in instrumental music. The

writer has tried to divide the octave into different numbers of parts, hoping to conciliate melody and harmony, but all in vain. Nothing better has been found, nor anything near as good as the present division of the octave into twelve equal parts.

The writer inclines to believe that it is so ordained by nature that there should be a difference between melody and harmony, the object of which is to improve instrumental music with a trembling which is very agreeable to ordinary ears, and its defect is perceived only by the most sensitive ears, of which there are very few even among musicians.

Good singers, tenors particularly, often put on this trembling artificially, for the purpose of producing better effect.

In an article on "Experiments on Sound for the Application of Ringing Bells," published in the JOURNAL OF THE FRANKLIN INSTITUTE for April, 1856, the writer gave a table for the tempered intonation with the scientific pitch, making C = 512 vibrations per second; but this table was found to be inconvenient in practice, for which the Stuttgart pitch, with more complete tables, was adopted as explained in the May number of the JOURNAL, 1882, which tables have been in practical use for many years. The formulas for the bells can, however, vary the pitch *ad libitum* whilst using the same tables.

Electric Resistance of a Vacuum.—Edlund thinks that his theory removes all difficulty from the explanation of the electrical and magnetic influences, which different cosmical bodies appear to exert upon one another. If a vacuum is a good conductor of electricity, any electrical disturbance upon one heavenly body must exercise an induction upon others, so that stars and planets may be connected not only through universal gravitation, and through the radiation of light and heat, but also through electric energy. The opposition, which men have hitherto thought to exist between the great height of the aurora above the earth's surface and the electric nature of that phenomenon, loses all meaning. The belief that electricity requires ordinary matter for its propagation must be given up, and the term *conductibility* loses all physical significance. Different material bodies only interpose a greater or less opposition to the spread of electricity, thus exerting not an active but a passive influence.—*Ann der Phys. und Chem.*. XV, 32. C.

AN ORGAN PIPE SONOMETER.

By W. LeConte Stevens.

The discussion of just intonation in connection with the development of the laws of vibration of stretched cords does not occupy much time in the usual course of instruction in acoustics, partly because it is considered as the musician's specialty, and partly on account of the tedious tables of vibration numbers to which the student's attention must be invited. The subject in its relation to the intonation of chime-bells has been well presented quite recently in this journal by Mr. John W. Nystrom.* Some time ago I devised a method of presenting it with the aid of the sonometer, by adjusting division marks on one edge of the sound board to give the proper cord lengths for the natural scale, and on the other edge for the scale of equal temperament. In doing this no attempt was made to adjust the cord lengths of the tempered scale to produce vibration numbers in arithmetical progression with constant differences in different portions of the octave, as recommended by the Stuttgart Congress and criticised by Mr. Nystrom. I deduced the formula, and calculated by aid of logarithms a table of vibration numbers and cord lengths, identical with part of what Mr. Nystrom has just published, assuming that the geometric ratio,

$$r = \sqrt[12]{2} = 1{\cdot}059462,$$

which I had readily obtained, was in general use.† The reciprocal of this,

$$r' = {\cdot}943877$$

gives the common ratio for the geometrical series of cord lengths, by which the twelve semi-tone intervals of the scale of equal temperament are secured. My sonometer was described at the Cincinnati meeting of the American Association for the Advancement of Science, a brief abstract of the description having since been incorporated in the journal of proceedings. The instrument has been still further improved, and a description may now be worth giving.

The resonance-box consists of a double organ-pipe made of spruce,

* This journal, May 1882, p. 367.

† Airy on sound, p. 224. Macmillan, 1871.

which is rested horizontally on the lecture table. The two embouchures are on opposite sides, one being turned toward the operator, as in Fig. 1. The air-blast, from either the lungs or a pair of bellows, may be forced into either one or both pipes at will through India rubber tubes. The interior dimensions of each pipe are 52 mm. by 62 mm., the length being adjusted to give as fundamental note, C, 132 vibrations per second; the effective length is hence a little over 125 cm., which is the length of the sonometer. At the side of the open end of one pipe is a sliding plate (a), by which it may be thrown out of unison with the other, thus producing beats. A stop may be thrust, by means of its handle, half way into one of the pair, converting it at will into a stopped pipe whose fundamental is the same as that of the open pipe of double its length. The union of double organ pipe

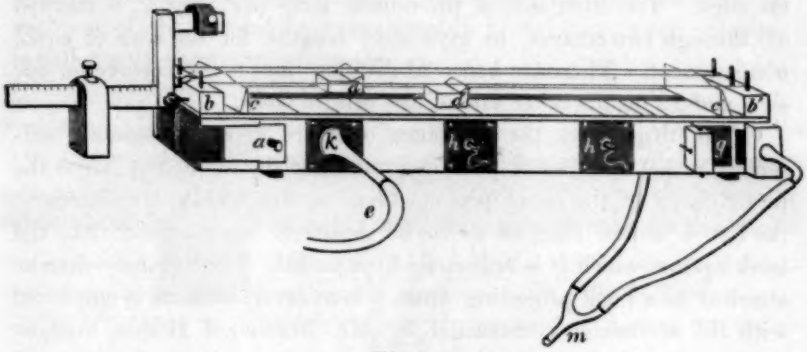


Fig. 1.

with sonometer is attended with some advantages, particularly in connection with the exhibition of Bernoulli's laws, since every note of the harmonic series can be secured with certainty from the stretched wire; and if this be tuned into unison with the fundamental of the organ pipe, a ready standard of pitch is close at hand for comparison with the corresponding harmonics of the organ pipe, which are not always obtained with equal ease, or with entire purity of tone.

The upper wall of the double pipe consists of a single plate of spruce, 5 mm. thick, that forms the sound board of the sonometer. Firmly fixed at each end is a block of hard wood (b, b'), into which piano pins have been driven for attachment of three steel wires which pass over the fixed bridges (c, c'). The latter are exactly one metre apart, in contact with the ends of a strip of wood divided at each edge

into millimeters, and occupying the middle of the sound board. Such a strip may be obtained for a trifle from the American Metric Bureau; it not only serves as a guide for the movable bridges (*d d'*), but makes it easy to mark off the division lines at their proper places. A longitudinal line divides its surface into two equal parts; that on the side toward the operator is marked off to give cord lengths for the natural scale, by changing the fractions $\frac{8}{9}$, $\frac{4}{5}$, $\frac{3}{4}$, etc., into decimals. The results are indicated, correct to three places, on the millimeter scale. Three octaves in succession are thus marked off: the lines for the first octave extending across to the edge of the sound board, as in Fig. 2, which represents a part of the instrument viewed from above. By multiplying each of these lengths successively by $\frac{135}{128}$ and $\frac{128}{135}$ we obtain cord lengths for the chromatic intervals of the natural scale. These are marked off for two octaves, the lines extending half way to the edge. The other side of the central strip (*e e'*, Fig. 2) is marked off through two octaves, to give cord lengths for the scale of equal temperament. There are hence 21 division lines to each octave on one side, and 12 on the other side of the central strip.

Of the three wires, the two outer ones are kept permanently unisonant, or as nearly so as possible, sounding the same note, C, as the fundamental of the organ pipes. That in the middle terminates at the left in a stiff ring, so as to be detached in a moment from the hook against which it is ordinarily kept pulled. The ring may then be attached to a hook projecting from a bent lever, such as is employed with the sonometer constructed by Mr. Ritchie, of Boston, to show the law of variation in tension.

Since the tension of the outer wires is kept constant, each division mark in both natural and tempered scales is distinctly labeled, as shown in Fig. 2. The movable bridges are painted black at their front edges, so as to contrast strongly with the white spruce on which they slide. Suppose the bridge, *d'*, to be adjusted so that its wire sounds E of the natural scale, while its companion, *d*, is adjusted to give E of the tempered scale. The difference in pitch is nearly a comma, and can be detected at once by a good ear. But this is additionally made visible by turning the sonometer toward the audience and resting it on its narrow side; the difference in position of the two bridges being easily detectible even when the ear fails to distinguish between the two sounds. Every note in the two scales can thus be compared in a few moments, starting with C as key note.

The necessity for temperament, and yet the unavoidable error of a tempered scale, is still better shown by taking some derived key for comparison; for example, that of G. For this purpose a separate strip (f, f' Fig. 2), properly marked off, is placed at the side of the central strip, the movable bridge being grooved below to slide over it. It is prepared by marking a strip whose length is $\frac{2}{3}$ metre at distances $\frac{8}{9}$, $\frac{4}{5}$, $\frac{3}{4}$, $\frac{2}{3}$, $\frac{8}{5}$, $\frac{8}{15}$, $\frac{1}{2}$, and then discarding the unmarked half. Placing the initial extremity of this scale in contact with the division mark, G, of the tempered scale, which in this case sensibly coincides with that of G on the natural scale, it is seen that the second note, if correctly tuned, would be a trifle higher than tempered A, and decidedly higher than natural A; the third would be lower than tempered B and unisonant with natural B; the fourth unisonant with both tempered and natural C, etc. Such a strip can be constructed for each one of the derived keys employed in music, though the principle is sufficiently shown with but one.

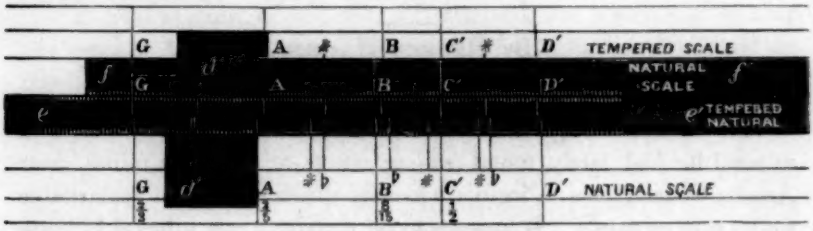


Fig. 2.

The division marks, $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, $\frac{1}{5}$, $\frac{1}{6}$, etc., each labeled with the name of the corresponding note, C′, G′, C″, E″, G″, etc., as well as with the figures composing the fraction, render it easy to obtain with quickness and accuracy the first dozen notes of the harmonic series, besides facilitating experiments on co-vibration.

To obtain the harmonic series from the open organ pipe it is found convenient to modify the size of the embouchure, and also the diameter of the pipe. For this last purpose a piece of wood, 120 cm. long, 6 cm. wide, and 2 cm. thick, is thrust into the pipe next the operator, thus diminishing the volume of air set in motion, and increasing the ratio of length to width. A sliding plate (g, Fig. 1) of thin sheet-iron serves to narrow the embouchure at will. Eight or ten successive notes of the harmonic series are thus secured and compared at the same time with those obtained by aid of the wire and labeled scale.

The stop can then be thrust into one pipe, and several of the odd series of harmonics elicited.

The wall of the pipe next the operator is perforated with three small holes, at distances approximately $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$, from the open end. These are kept stopped with plugs, which may be removed at will. Immediately around them the wall is covered with sheet rubber (h, h_1) to secure an air-tight fit for the mouth of the funnel (k) from which a tube (l) conveys waves to a manometric capsule. The position of nodal points in the air column is thus shown. By fitting the tube (l) upon a Y-tube, like that shown at m, and interposing between this and another Y-tube a pair of India rubber tubes, one of which is longer than the other by a half wave length, making allowance for friction, the apparatus is readily utilized for illustrating interference, with the aid of the manometric flame.*

New York, May 4, 1882.

ANALYSIS OF HELVITE FROM VIRGINIA.

By Reuben Haines.

[Read before the Chemical Section, Franklin Institute, May 2, 1882.]

The writer was requested by Mr. Henry Carvill Lewis to analyze a mineral he had lately found among others at the mica mines, near Amelia Court House, Virginia, a locality which has become remarkable for its rare minerals. It appears to be Helvite, a rare mineral hitherto found only in Europe; in Saxony, Norway and Finland. It is a silicate of glucina and manganese, containing ferrous sulphide and manganese sulphide. It occurs in yellow crystals and crystalline masses associated with orthoclase and garnet.

The following mineralogical determinations were made by Mr. Lewis. The crystals were shown by the polariscope to be isometric, but were not sufficiently perfect for angular measurement. Hardness about 6; color sulphur yellow; lustre somewhat resinous; partially translucent; fusibility about 4, with intumescence to a brown glass. The mineral gives no water in closed tube; with fluxes reacts for manganese; soluble in hydrochloric acid with evolution of hydrogen sulphide and separation of gelatinous silica.

The specific gravity which I determined myself was 4·306.

* We are indebted to *Am Jour. Science and Arts* for the use of the cuts illustrating this article.

The results of my analysis are as follows:

Silicious gangue,	9·22	32·32 per cent.
SiO_2 (gelatinous),	23·10	
BeO,	11·47	
Al_2O_3,	2·68	
MnO,	45·38	
FeO,	1·85	
CaO,	·64	
K_2O,	·39	
Na_2O.	·92	
S,	4·50	
Ignition (moisture),	·30	
	100·45	
Less oxygen replaced by sulphur	2·25	
	98·20	

The total amount of the mineral obtained was scarcely more than one gram. About ·72 gram was reserved for general analysis, and the remainder was used for determination of specific gravity, sulphur and moisture.

The method of analysis pursued was as follows:

The powdered mineral was dissolved in hydrochloric acid, evaporated to dryness, filtered, and the residue treated on the filter eight times with hot concentrated solution of sodium carbonate, and finally washed thoroughly with hot water. Ignition of the residue gave the siliceous gangue insoluble in acid and in sodium carbonate. There was thought to be less risk in washing on the filter than by boiling up in a beaker and refiltering. The total silica plus gangue was obtained by weighing the residue of silica from the estimation of sulphur for which about $\frac{1}{10}$ gram was used. The difference between these two estimations gave the gelatinous silica. The Fe_2O_3 and Al_2O_3 were separated from MnO and BeO by first repeated precipitation by ammonia, and finally by protracted boiling with concentrated solution of ammonic chloride repeated four or five time to dissolve out all the glucina (Berzelius' method). The Fe_2O_3 and Al_2O_3 were weighed together and titrated by permanganate in the usual way. The glucina and manganese were separated by double precipitation by ammonia, being careful to avoid excess, heating as short a time as possible and filtering

soon to avoid resolution of the glucina. The manganese was precipitated by bromine and then by sodium phosphate and was weighed as pyrophosphate. The filtrate from the calcium oxalate, after testing for magnesia, was boiled with barium hydrate to obtain the alkalies which were separated by platinum chloride, and the ignited platinum weighed.

The sulphur was separated and oxidized by dissolving the mineral in hydrochloric acid, to which bromine had been added.

For the specific gravity dermination ·28 gram was used. It was made in a ten-gram specific gravity bottle with great care as to temperature and all other necessary precautions.

The moisture was determined in a separate portion the weight of which was 83 milligrams, by direct absorption in a chloride of calcium tube attached to a combustion furnace.

By reference to Dana's mineralogy, it will be seen that my determination of the specific gravity differs materially from that given for Helvite. Yet in all other respects, both physical and chemical, except the manner of regarding the silica, the analysis given above agrees very well with that mineral. Dana gives the specific gravity as 3·1 to 3·3; mine is 4·3. Any slight impurity in my specimen in the form of garnet or feldspar would tend to lower instead of raising the specific gravity.

As regards the silica, it will be noticed that in former analyses the amount given is 33·26 to 35·27 per cent. in two analysis by Gmelin; 33·13 per cent. in one analysis by Rammelsberg, and 30·31 per cent. in one analysis by Teich. If the gangue and gelatinous silica in my analysis are added together we have total silica 32·32 per cent. It appears to me, however, that either we must regard the gelatinous silica alone as a legitimate part of the true species and consider the "gangue" as accidental impurity, or we must consider the silica of the true mineral as existing in two distinct molecular conditions. The latter hypothesis is scarcely tenable, while the former would require a formula quite different from that given by Dana for Helvite.

THE ABSORPTION OF METALLIC OXIDES BY PLANTS.

By Francis C. Phillips.

[Paper read before the Engineers' Society of Western Pennsylvania, Tuesday, February 21, 1882.]

The question how far the vital processes of plants are influenced by the various mineral compounds presented by the soil to their roots has long been under discussion in physiological botany, but further than to establish the fact that the presence of certain compounds in soil tends to increase the nutritious elements, and promote the growth of particular vegetables, little has been done towards a complete solution of the problem.

It is well known that potash tends to increase the quantity of starch, that silica strengthens the stems of the grasses, that oxide of iron is essential to the production of leaf-green, that phosphates increase the fertility of the soil for cereals, but even as regards these constant elements of every soil, very little can be positively asserted of the precise influence of any one, in the economy of the plant.

Concerning the part played by the rarer elements, caesium, rubidium, copper, nickel, manganese, zinc and barium, in the assimilation of carbon, nitrogen, and the functions of nutrition, and whether they are beneficial or injurious, nothing whatever is known, although modern refinements in chemical methods have led to their frequent detection both in soil and in plants. That so important a problem should have remained almost wholly unsolved must be attributed chiefly to the very great difficulties which are met in any experimental investigation, but also to the fact that the few investigations published have been carried out, in most cases, for the purpose of proving that vegetation had been injured by metallic compounds traceable to a metallurgical works, and with the special purpose of founding a claim for damages, rather than to solve a scientific problem. The study of the influence of metallic compounds on plants has recently acquired great practical importance, from the fact that many manufacturing processes, more especially those employed in the smelting of lead and copper, and arsenical ores of various metals, have given rise to a gradual impregnation of the soil with such metals, and to the consequent poisoning of vegetation and animals.

In almost all cases where furnaces for the treatment of such ores have been erected, there has followed a serious injury to vegetation, caused by the metallic vapors and dust escaping from the flues; while the lawsuits instituted to recover damages have brought forward many interesting facts as to the extent of vaporization of metals, the necessity and difficulties of providing proper means for condensing the noxious fumes, the evidence has seldom furnished any definite information as to the more general question at issue.

The possibility of injury to plants from such sources has been denied under an assumption that plants, like animals, possess a certain discriminating power, and that they are able to select and take up through their roots, such elements of the soil as are nutritious, and to reject all else, a view which is very commonly accepted, and has been held by high authorities.

With the very much less complete condensing apparatus in use in former times, the injury caused by such establishments was far greater than at present, but even at smelting works where the most improved machinery is in use, it is often difficult to prevent the escape of large quantities of poisonous mineral compounds, which in the shape of dust may be carried many hundred yards and scattered with injurious effects upon vegetation.

As early as the year 1668 mention is made of the injury to pastures, caused by lead fume, by Joseph Glanvil, who published a description in the "Philosophical Transactions" of the smelting of lead ores in the Mendip Hills.

This author says "there is a flight in the smoak, which, falling upon the grass, poysons those cattel that eat of it. They find the taste of it upon their lips to be sweet, when the smoak chances to fly in their faces. Brought home and laid in their houses, it kills rats and mice.

"If this flight mix with the water in which the oar is washed, and be carried away into a streame, it hath poysoned such cattel as have drunk of it after a current of three miles."

Richard Watson, in his "Chemical Essays," published in 1799, calls attention to the saving to be effected, and the protection afforded to pastures, by the use of long horizontal chimneys, for the condensation of lead fume, in Derbyshire.

"But so difficult is it," says this author, "to wean artisans from their ancient ways that I question whether any of them would ever have adopted the plan they approved, if an horizontal chimney which

was built in Middleton Dale to protect pastures from the smoke of the furnace, had not given them full proof of the practicability of saving the sublimate of lead which is lost in the ordinary method of smelting."

Among more recent cases, the following, cited by Taylor, in his "Treatise on Poisons" (3d American edition, p. 424), is of interest: "It was alleged on the part of the plaintiff that a large number of sheep and cattle had been destroyed by fumes of lead escaping from a chimney on the defendant's works. The case involved this curious point, namely: admitting the sheep and cattle to have been destroyed by lead, whether the lead was deposited on the herbage from the defendant's chimney, or taken up by the plants from the soil, and incorporated with their tissues. The condensing arrangements at the lead works were found to be almost absolutely complete, and there was not the slightest appearance of a deposit of white lead on the herbage. But it was found that the herbage was impregnated with lead, and that seeds sown in the leaden soil, brought for this purpose to London, produced plants containing lead. The soil had derived the lead from ancient mineral workings."

Dr. Wilson ("Edinb. Monthly Journal of Medicine," 1852), in a case somewhat similar to that cited by Taylor, of cattle poisoning by lead, found the herbage to contain the metal, and that beans grown upon a portion of the soil were impregnated in the same manner.

The results seem to point very clearly to the possibility of the absorption of lead by the roots of plants.

An exhaustive investigation into the action of copper and zinc on vegetation has been made by Dr. Freytag, of the Agricultural Laboratory in Bonn,* and the results published in an official report upon the injury alleged to have been caused by the smelting furnaces of Mansfield. In the neighborhood of Mansfield, furnaces have been in operation for several centuries, and the soil in many places has in consequence became greatly deteriorated as regards its fertility, being charged with as much as 10 lbs. of oxide of copper and 24 lbs. oxide of zinc, to the ton of earth. In order to test the influence of these metals upon the nutritive qualities of the crops, Freytag made comparative analyses of clover and grass grown in the neighborhood of the smelting

* "Wissenschaftliches Gutachten über den Einfluss, welchen die Hüttenwerke der Mansfelder Kupferschieferbauenden Gewerkschaft auf die Vegetation und indirect auf Menschen und Thiere ausüben" Von Dr. Moritz Freytag. Eisleben, 1870.

furnaces, and of similar plants grown five miles distant, but under as nearly as possible the same conditions of temperature, moisture and manuring. The plants from the neighborhood of the furnaces differed in the following points from those grown at a distance.

1. They contained in their ashes varying quantities of the oxides of copper and zinc, as much as 0·2 per cent. oxide of copper, and 0·36 per cent. oxide of zinc.

2. There was a larger per centage of sulphuric acid, attributed by Freytag to the fact that the copper and zinc occur in the soil as sulphates.

3. The proportion of nitrogenous bodies was greater by 25 to 30 per cent. (2 per cent. of the dried plant). As regards the assimilation of nitrogen, therefore, the metallic sulphates were apparently beneficial.

Very interesting experiments have been made by Freytag upon the capacity of plants to absorb solutions of metallic salts.

Beans, peas and other seeds were allowed to germinate in a solution containing nutritious matters, and after maturing, were transferred to solutions containing arsenious acid, the sulphates of iron, cobalt, nickel, zinc and copper.

The result was that a solution containing $\frac{1}{80}$ per cent. arsenious acid proved fatal, as was also the case with $\frac{1}{25}$ per cent. sulphate of cobalt, $\frac{1}{15}$ per cent sulphate of nickel, $\frac{1}{50}$ per cent. sulphate of zinc, $\frac{1}{5}$ per cent. sulphate of iron.

No injurious effects were produced by more dilute solutions, the plants continuing to thrive until the poisonous limit of concentration was reached, when they rapidly withered and died.

In all cases there were found in their tissues small quantities of the respective metals in whose solutions they had been grown.

Freytag says: "I have found that plants growing in solutions of metallic salts are killed when the concentration reaches a certain degree, which is in all cases below 1 per cent. of the solution, and this statement applies equally to those salts which are essential to plant life. If we accept this as equally true of plants growing upon soil, it follows that the moisture of the soil must contain very small traces of mineral salts in solution, and by experiment it has been shown that the watery extract of a soil which is charged with salts of the heavy metals always contains less than the fatal dose of such metals."

Freytag thus sums up:

"It has been fully demonstrated that plants are not capable of

selecting from the substances presented to their roots, that they are on the contrary, compelled to take up all matters alike, which are in a form fitted for absorption, but that matters insoluble in the moisture of the soil are never taken up in sufficient quantities to endanger the life of the plant."

Freytag claims as his own, the theory of non-discrimination of plants, but Liebig in his "Agricultural Chemistry," (4th English edition, page 66), states that "all substances in solution in a soil are absorbed by the roots of plants, exactly as a sponge imbibes a liquid, and all that it contains, without selection."

Freytag has detected zinc and copper in the leaves of oaks and birch trees in the Mansfield district, and in a series of experiments it was found that zinc added to soil in the form of carbonate is absorbed by rye, wheat and maize, and is deposited in the leaves, stems and seeds. Many plants growing near zinc mines absorb considerable quantities of oxide of zinc, and in two well-known cases new varieties are considered to have been produced by soil containing zinc, one a shepherd's purse (Thlaspi alpestre, variety calaminaris), the other a violet (Viola tricolor, variety calaminaris.)*

The latter plant is considered by some authorities to be a distinct species. The ash of the leaves of this violet contains 13 per cent. oxide of zinc. Both of these plants are confined to localities where zinc is an element of the soil, and the zinc seems therefore to be an essential constituent.

Among the strongly poisonous metals, zinc appears, according to the investigations published, to be the most readily absorbed by plants. It is of singular interest, however, that experiments conducted in the botanical garden at Erlangen, have led to a negative result, as regards the possibility of its absorption, contradicting, therefore, those obtained by Freytag.

In the report of the Commissioner of Agriculture (Washington, 1875), some experiments are described upon the action of Paris green on vegetation. Peas were sown in soil containing varying quantities of Paris green. No injurious effects were produced where the quantity of the arsenical compound was less than 900 lbs. per acre of soil. When present in larger quantity, the plants were feeble and were smaller in proportion as the arsenic was increased. With 1½ tons of Paris green to the acre the seeds failed to germinate. The plants were

*Johnson, "How Crops Grow," page 196.

tested for arsenic but were found to have not absorbed even traces of the metal recognizable by Marsh's test.

These results involve therefore a direct contradiction of Freytag's theories, both as regards the non-absorption of the metal, and as regards the vital processes of the plant. According to Heckel ("Comptes Rendus," vol. lxxx, p. 1172), water containing $\frac{3}{1000}$ per cent. of arsenious acid prevents the germination of seeds and destroys the embryo plant.

For the purpose of throwing some light on this difficult problem of the influence of metallic oxides upon plant life, a series of experiments was carried out during last spring in the greenhouse of the Allegheny park, by the kind permission of the superintendent of the park, Mr. William Hamilton.

The object of these experiments was to determine, firstly, whether any injurious effects are produced upon plants by being grown in soil impregnated with certain metallic oxides; secondly, whether plants in a perfectly healthy state will absorb such oxides through their roots. In the early spring the greenhouse was filled with very young plants, in a vigorous condition of growth, which were being reared for the purpose of supplying the park in the summer. The plants selected were geraniums, coleas, ageratums, achyranthes and pansies. This selection was made, not with reference to any special peculiarities of the plants, but for the reason that there were thousands of other plants of the same kind, and all equally advanced in growth, on the tables of the greenhouse, which afforded an opportunity for a close comparison of those grown upon poisoned soil with others grown under normal conditions.

The compounds used were the carbonates of zinc, copper and lead, and as an arsenical compound, arsenate of lime. These compounds are almost absolutely insoluble in pure water.

The method of setting the plants was that commonly employed by gardeners in transplanting. Young plants, with their roots as nearly as possible intact, were placed in flower pots, and soil previously mixed with a weighed quantity of the metallic compound was poured in and pressed down around the roots. The first series included ageratums, which were grown in soil containing $\frac{1}{2}$ per cent. white lead.

The second series consisted of geraniums, which were grown in soil containing $\frac{1}{2}$ per cent. carbonate of zinc.

The third series included achyranthes. The soil supplied to them contained $\frac{1}{2}$ per cent. carbonate of copper.

The fourth series were coleas, which were grown in soil containing ½ per cent. arsenate of lime.

The fifth series included coleas, grown in soil containing ¼ per cent. arsenate of lime.

The sixth series were pansies, grown in soil containing ½ per cent. carbonate of zinc.

All these plants enjoyed the usual careful greenhouse nursing, and as regards temperature, moisture and fertility of the soil, the conditions were absolutely the same as in the case of the other plants, excepting the poisonous influence to which their roots were exposed.

The progress of each plant was watched and a record kept. On the 10th of June, eleven weeks after the commencement of the experiments, the plants were cut off above the roots, and those of each series subjected to analysis, with the following results:

The ageratums, grown in leaden soil, matured and produced flowers as early as the most advanced of those grown in ordinary soil. Their roots were very abundant and healthy, the only noticeable effect of the lead being that the leaves were of a yellowish hue. The analysis showed that lead had been absorbed in small quantities.

In the second series geraniums were reared in soil impregnated with carbonate of zinc. The plants were in every respect normal, bore flowers and produced abundant roots.

The analysis showed considerable quantities of zinc.

In the third series, achyranthes were grown in soil containing carbonate of copper. The effect of the copper was not visible in the plants at first, as they continued to grow rapidly, and were normal in color. But in maturing, the bright leaves became darkened. It was found that the copper had killed the original roots, and totally arrested the development of new ones. The plants had apparently been nourished from the air alone. Very small quantities of copper were found in their ashes.

The most strongly marked results were produced in the case of the arsenic. In the fourth series, coleas were grown in soil containing ½ per cent. of arsenate of lime. The effects of the poison were visible in a few days, the plants languishing and producing but few leaves. In the course of two weeks all were dead.

In the fifth series, coleas were reared in soil containing ¼ per cent. of arsenate of lime. The plants were feeble from the first, produced but few leaves, which were normal in color. Although they endured

with greatly diminished vitality, no increase in growth took place, and the stems were not strong enough to remain erect. In all cases the arsenic had totally destroyed the roots. Traces of arsenic were found in the analysis.

In the sixth series, pansies, grown in soil containing carbonate of zinc, produced abundance of roots and continued healthy. Analysis proved the presence of zinc in considerable quantities.

In view of conflicting statements of authorities, further experiments on a large scale, and extended to a wider range of plants, grown under varying conditions, would be needed to establish any general laws in regard to the absorption and influence of metallic poisons contained in soil upon vegetation. The discovery of these laws would probably lead to the discovery of methods for the prevention of such influences, so far as they are of a dangerous character.

From the experiments detailed above it seems safe to conclude, however:

1. That healthy plants grown under favorable conditions may absorb through their roots small quantities of lead, zinc, copper and arsenic.

2. That lead and zinc may enter the tissues in this way without causing any disturbance in the growth, nutrition and functions of the plant.

3. That the compounds of copper and arsenic exert a distinctly poisonous influence, tending, when present in larger quantity, to check the formation of roots, and either killing the plant or so far reducing its vitality as to interfere with nutrition and growth.

In the case of the heavy metals, copper, zinc, arsenic and lead, it seems to be probable that their oxides may under certain circumstances become deposited in the tissues of the plant. As to the manner in which this takes place, authorities differ.

It is supposed by Freytag and others, that plants absorb all soluble matters indiscriminately, through their numberless rootlets, that the absorption of poisonous metals causes no disturbance until a certain degree of concentration is reached, when the plant rapidly withers and dies; that plants are therefore spared the sufferings of chronic poisoning, but are very susceptible to acute poisoning, which is invariably fatal; while it is held by others that plants absorb only such elements as are essential and nutritious, refusing to take up what is poisonous

or innutritious; metallic compounds found in the analyses are therefore to be traced to atmospheric deposit adhering externally.

The theory of Freytag seems to have the weight of facts in its favor, and if it is possible that crops may become charged in this way with poisonous elements of the soil, it becomes a matter of the highest importance that wherever there is danger of such impregnation the most efficient means be employed for its aversion; for soil once impregnated with copper, lead and zinc, may year after year bear crops poisoned in the same manner.

APPLICATIONS OF THE PRINCIPLE OF THE PHONODYNAMOGRAPH.

By WILLIAM B. COOPER.

[A Paper read at the Stated Meeting of the Franklin Institute, May 17, 1882.]

Upon the evening of the last meeting of the Institute, I gave a brief description of a device for augmenting the dynamic effect of the vibrations of diaphragms, and directed attention particularly to its application to the production of a record of such pulsations in much thicker metal than was heretofore thought possible; on account of the interest manifested by those then present, I have brought the device again before you with the view of entering more at length into its applications.*

When a cord is passed over a revolving pulley, it is well known that there is a pull upon one side proportioned to the character of the surfaces in contact and the pressure upon them. This pull is due to the friction of the surfaces upon each other, and increases in approximately (if not exactly) the rame ratio as the pressure; now, if the pulley is loose upon the shaft and we draw upon a cord passing over it, we have the same force exerted at the other end of the cord minus the friction at the shaft; if, however, the pulley is attached to the shaft and is rotating towards the end drawn upon, then the result at the other end will be the force applied, plus the amount derived from the friction upon the surface of the pulley. This is the principle of

* Since the above was presented, Mr. Cooper has devised a method of accomplishing this result in a radically different manner, although upon the same general principle. This he intends to bring before the Institute at an early day.

my device. To one end of a wire or band, *B*, Fig. 1, I attach a diaphragm or other pulsating body, *C*, and then give a half turn or several turns around a drum or pulley, *A*; to the other end may be attached a lever, *D*, having a point adapted to the indentation of sheet-metal passed under it at a uniform speed; this may be accomplished by any suitable mechanism. In this form I have termed it the "Phonodynamograph," and my experiments have already resulted in embossing brass of the thickness of writing-paper by the impact of the voice upon a diaphragm of the size used in the phonograph.

This principle is, without doubt, applicable to the telephone, both for the purpose of increasing the intensity of the electric impulses transmitted, and augmenting their effects at the receiving station. At the transmitting station, for example, the same, or by means of leverage, a greater amplitude of vibration may be given to a stouter dia-

Fig. 1.

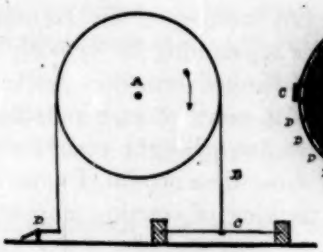
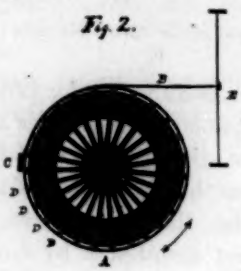


Fig. 2.



phragm, or an armature controlled by a spring, playing before the poles of a magnet. It is manifestly applicable, however, to any form of transmitter in which increased power is advantageous. By it the telephone may be rendered available for greater distances.

Having augmented the electric impulse at the transmitter, we may add to it an increment derived from an auxiliary power at the receiver. This may be done in several ways: the vibrations of a receiving diaphragm, or an armature in combination with a spring may be augmented and made to operate a second diaphragm or a recording point. As the dynamic effect of the telephonic impulse is at best but feeble, I have devised a method of dealing with it which appears to me cannot but produce some very striking results.

If a number of electro-magnets, *D*, *D*, *D*, *D*, Fig. 2, preferably of the horseshoe form, are arranged radially in a drum or pulley, *A*,

composed of some non-magnetic substance, at right angles to its plane of motion, with their poles flush with its face, it is clear that if an armature, *C*, is placed in contact with the face of the drum and it is rotated, the armature will be drawn in the direction of the motion of the poles of the magnets whenever an electric impulse passes through their helices; the extent of this motion will depend upon the inertia of the armature, the resistance applied to it, and the strength of the electric impulse, etc. If the number of magnets is such that the distance between their poles at the face of the drum is somewhat less than the width of the armature, and each succeeding magnet makes electric connection before the preceding one has parted from the armature, then there will be a continuous draft upon the armature as long as the electric impulse lasts, subject to the above-mentioned influences; there will clearly be a sensitiveness to slight magnetization owing to the continuous intimate contact of the armature with the poles of the magnets. If we now connect to the armature a wire or band, *B*, and give it one or more turns around the drum in the opposite direction to its motion, we will have the draft upon the armature augmented by an increment derived through the agency of friction from the power applied to rotate the drum. The other end of the wire or band may be attached to a diaphragm, *E*, or it may be connected to recording mechanism.

At the work-end of the wire or band the normal tension may be reduced to a minimum by an adjustable spring, while the friction may be increased by increasing the number of coils, the size of the drum, or the nature of the surfaces. A light spring may also be found advantageous at the slack end under some circumstances.

Instead of a wire or band, a chain, one or more shoes hinged together, or coupled by a cord, wire, band or chain, may be used.

The magnets used in the drum may be small, as magnetization and demagnetization is said to be more rapid in small than in large cores. If made in the horseshoe form, as suggested, their poles should be sufficiently separated to leave a zone of uninterrupted friction surface in the middle of the face of the drum. The face of the armature in contact with the drum has a notch or recess over this middle zone to give the band free play.

The principle applied in the above cases is also applicable to the mechanical telephone. It may also be used to reproduce the record in increased sound, as by giving a diaphragm greater amplitude of

motion, a louder tone results. A large diaphragm having a funnel or trumpet attached to it, through the intervention of this device may, by means of leverage, be made to vibrate with greater amplitude than the smaller diaphragm at which the pulsations originate. This will be a simple method of increasing the power of the voice in the many cases where that is desirable.

I have also devised improvements in recording the vibrations of diaphragms, etc. A small burr or circular saw, revolving at considerable velocity, may be used, its plane of motion being at right angles to that of a strip, plate or cylinder against which it is pressed by the pulsations of a diaphragm; or, it may be made to notch the edge of a strip. If it is desirable the burr or saw may be stationary, and a strip may be pressed against it by a small roller, or other device, operated by the diaphragm.

In the case of indenting metal with a stylus, the metal may be acted upon while softened by heat. A strip might be heated by an oxyhydrogen jet just before passing under a stylus of some refractory substance; and in the case of a strip of steel, it might be tempered by passing it immediately into water, or oil, or cotton waste, or some similar substance saturated with them. In this case, also, the stylus or point may be fixed and the strip pressed against it, if that method should be found more desirable.

Distribution of Dark Heat.—P. Desains has investigated the distribution of heat in the obscure region of the solar spectrum. The diathermancy of the air is continually varying on account of the variable degrees of moisture which it contains. The radiations of the luminous part of the spectrum are only slightly absorbed, but the dark rays are largely so, and in a ratio which generally increases with the length of the wave. In order to measure these influences, the observations have been compared with others upon the transmissibility of the total solar heat through a uniform thickness of water. Prisms of flint and crown glass and rock salt, of which the indices have been accurately determined, are employed in these measurements. Desains has already obtained data which enable him to construct the curves which represent the distribution of heat in the dark spectrum, and he proposes soon to publish some valuable comparative results.—*Comptes Rendus*, civ, 1144. C.

REMARKS MADE AT THE CLOSING EXERCISES OF THE DRAWING SCHOOL, MAY 18, 1882.

By Coleman Sellers, Jr.

It seems perhaps scarcely necessary to try to offer any encouragement to those who are doing successfully so excellent a work as that whose results we have before us this evening—hardly necessary to commend the scholar for making the most of the opportunities offered him or the instructor for doing his duty faithfully and thoroughly. But it may be of interest for both to receive the assurance that, in the opinion of those who have watched their progress, the work they have done has been in the direction from which they may expect to obtain the greatest benefit. The term "drawing" comprehends operations vastly dissimilar—in fact, it comprehends operations so dissimilar and results so diverse that it can scarcely be described by a general definition less comprehensive than that of Hamerton who defined drawing as a "*motion which leaves significant marks.*" This alone will include that vast range which lies between the finished work of the great painter and the crude sketches of the savage, or the cruder efforts of childhood with pen and pencil.

In every case the drawing depends not alone upon the skill of the draughtsman, but also upon the facilities at his disposal and the kind of information he desires the drawing to impart. For example, the drawing which is made by the gas-fitter, by which to get out his pipes and fittings, bears to the uninitiated eye no resemblance to the completed work, but it conveys to the mind of one skilled in the art a clearer notion of what is wanted than the most elaborate picture could convey.

Scientists tell us that the earliest draughtsmen of whom we have any knowledge were the cave-dwelling men of Europe, who belonged to a race that passed away hundreds or perhaps thousands of years before the commencement of the era in which we live. This curious people, about whose lives and appearance our knowledge is at best only careful guessing, have left behind them drawings made with a sharp piece of flint, most likely, upon the bones and teeth of the strange animals they slew, and these drawings are said to convey correct ideas of

form and appearance, and give us some proper notions of what they saw around them. In fact, so good are they that the naturalist is able to identify the *genera* and *species* of the animals represented. In this respect these drawings were unlike a child's early sketches, although perhaps those primitive people were but children in the scope of their minds and faculties. The child, you know, generally begins by drawing man as a couple of triangles joined at their points, or sometimes like a "figure eight," with four straight marks for arms and legs.

As I have said, industrial drawing varies to suit the different crafts or trades with which it is associated. The pupils of the Franklin Institute Drawing Schools are mainly those who desire to obtain a knowledge of that branch of the art of drawing which applies most directly to the occupations of the machinist and the pattern maker. Now it so happens that the professional teachers of and writers on mechanical drawing, as this kind of drawing has been called, have generally not been those who have had occasion to make and use drawings in the way that draughtsmen and machinists use them and make them. The consequence of this has been that, in their efforts to form a thorough and logical system of drawing, they have followed chiefly certain preconceived maxims and principles, and have paid little or no attention to the system which has gradually been formed in the workshops, and which is based upon the actual requirements of the users of drawings and the convenience of the makers of them. Two systems have thus been formed, in many respects similar, but differing materially in some essential points and unfortunately, so it seems to me, the professional teachers of drawing have not in most cases followed the usages of the shops. From this difference between theory and practice has arisen much confusion and many misunderstandings, and more or less expensive mistakes have resulted. Now what I want particularly to say to the students of the Franklin Institute School is that they may rest assured that all that has been taught them is just of the kind which has been found to be of the greatest value in practice, and they will not be called upon to unlearn the lessons of the past year in order to acquire newer or more practical methods. No doubt many of them have discovered that more knowledge is required in drawing than they believed necessary, and perhaps they realize that facility in the use of drawing instruments is at best only one step in learning the art of drawing.

I trust, too, that this discovery will not be discouraging, but will

stimulate all to renewed exertions to perfect themselves in so valuable an art, and also, if possible, to push their inquiries still further into those branches of thought, such as geometry and algebra, which are so intimately connected with mechanical drawing.

CONSERVATION OF SOLAR ENERGY.

By Pliny Earle Chase, LL.D.

Some of the results of photodynamic elasticity, which have been already indicated in the Journal of the Franklin Institute, have acquired new importance from the recent discussions of the views of Dr. C. William Siemens.

If the so-called luminiferous æther is an atmosphere of great elasticity, in considering the influence of solar rotation upon luminous vibrations, regard should be paid to the centrifugal force, not only at Sun's surface, but also at all other distances from the centre of the system, where an appreciable disturbance may be looked for.

Let r_0 represent Sun's semidiameter, then Laplace's limit between rotation and revolution is at $36{\cdot}35r_0$. The centrifugal force of rotation at that limit is $36{\cdot}35^2$ times as great as at Sun's surface, while the centripetal force of gravitation is only $\frac{1}{1321\cdot3}$ as great. The photographs of the solar eclipse to which Dr. Siemens refers (*Nature*, April 20, 1882), unquestionably confirm his views, by indicating an atmospheric oblateness which may be due to the equilibrating tendencies of these two opposing forces.

If the æthereal disturbances which spring from this source are not sufficient to account for luminous and thermal vibrations we may look still further, to the velocity which subsiding particles would acquire in falling from Laplace's equatorial limit to the poles. If there were no resistance, the velocity would be $\left(\frac{35{\cdot}35}{36{\cdot}35} \times 2gr\right)^{\frac{1}{2}} = 376{\cdot}8$ miles per second. Any diminution of this velocity by resistance would be converted into heat. The mean limit between centrifugal and centripetal tendencies being in latitude 30°, the mean diminution of velocity, when the particles have reached the polar zone, is ·982 of 376·8 = 370 miles, representing a mechanical equivalent of 288,670,000,000 J for every pound of subsiding matter. The formula of torsional elasticity

(this journal, cxiii, 437), provides for radiations with the oscillatory velocity of light, and the tendency of nebulæ to a discoid or flattened form thus gains a new meaning.

The spiral descent of the subsiding particles, in their approach to the poles, gives rise to Ampérian currents, which account for Maxwell's identification of luminous and electro-magnetic waves; the axial core of the spirals is the rod of the virtual solar pendulum (*loc. cit.*), of which the length and the radius of torsion are both determined by the solar modulus of light; the continual succession of spiral impulsions converts reciprocal oscillation into uniform rotation; the *precise* accordance between the time of rotary oscillation and the time of acquiring or of losing the velocity of luminous projection, shows the equally precise agreement between centrifugal æthereal action and centripetal gravitating reaction; the combination of axial rotation with orbital revolution induces continual shiftings of inertial resistance, which must be followed by continual renewals of æthereal disturbance; the perpetual maintenance of luminous oscillation by influx, as well as by an equivalent efflux, removes the "reproach of Thermodynamics."

Such are a few of the obvious considerations which are suggested by the identity of luminous and gravitating oscillatory velocity at the centre of the solar system. In subjecting them to the tests of mathematical analysis, the equilibrating tendencies of centrifugal and centripetal action should be specially studied with reference to three oblate spheroids, all of which have the sun's poles for their common poles. Their equatorial loci are respectively coincident with Laplace's limit ($36{\cdot}35r_0$), the virtual radius of solar torsion ($688{\cdot}95r_0$), and the solar modulus of light ($474657r_0$).

Minima of Sun Spots in 1881.—A. Riccò found that the northern solar hemisphere was without spots on 23 days, the southern on 94 days. There were 12 periods of minima on the north, and 18 on the south of the equator. The intervals between the minima did not differ much from a solar synodic rotation. The centres of the minima of the northern hemisphere fall between 241° and 360°; those of the southern hemisphere are found in all longitudes, but with some accumulation between 56° and 70°. These facts show that solar activity is localized for a long time in certain regions of the sun's surface, as Tacchini had previously found.—*Comptes Rendus*, xciv, 1169.

C.

NEW THEORY OF THE SUN—THE CONSERVATION OF SOLAR ENERGY.

By C. William Siemens.

A paper was recently read by me before the Royal Society, under the above title, which may be termed a first attempt to open for the sun a creditor and debtor account, inasmuch as he has hitherto been regarded only as the great almoner, pouring forth incessantly his boundless wealth of heat, without receiving any of it back. Such a proposal touches the root of solar physics, and cannot therefore be expected to pass without challenge—to meet which I gladly embrace the opportunity, now offered to me through the courtesy of the editor of this review, of enlarging somewhat upon the first concise statement of my views regarding this question.

Man has from the very earliest ages looked up with a feeling of awe and wonderment to our great luminary, to whom we owe not only the light of day, but the genial warmth by which we live, by which our hills are clad with verdure, our rivers flow, and without which our life-sustaining food, both vegetable and animal, could not be produced.

When for our comfort and our use we resort to a fire, either of wood or coal, we know now by the light of modern science that we are utilizing only solar rays that have been stored up by the aid of the process of vegetation in our forests or in the forests of former geological ages, when our coal-fields were the scenes of rank tropical growth. The potency of the solar ray in this respect was recognized—even before science had discovered its true significance—by clear-sighted men such as the late George Stephenson, who, when asked what in his opinion was the ultimate cause of the motion of his locomotive engine, said that he thought it went by "the bottled-up rays of the sun."

With the exception of our coal-fields and a few elementary combustible substances, such as sulphur and what are called the precious metals, which we find sparsely scattered about, our earth consists essentially of combined matter. Thus our rivers, lakes, and oceans are filled with oxidized hydrogen, the result of a most powerful combustion; and the crust of our earth is found to consist either of quartz (a combination of the metal silicon with oxygen) or limestone (oxidized

calcium combined with oxidized carbon), or of other metals, such as magnesium, aluminium, or iron, oxidized and combined in a similar manner. Excepting, therefore, the few substances before enumerated, we may look upon our earth, near its surface at any rate, as a huge ball of cinder, which, if left to itself, would soon become intensely cold, and devoid of life or animation of any kind.

It is true that a goodly store of heat still exists in the interior of our earth, which, according to some geologists, is in a state of fusion, and must certainly be in a highly heated condition; but this internal heat would be of no avail, owing to the slow rate of conduction, by which alone, excepting volcanic action, it could be brought to us living upon its surface.

An estimate of the amount of heat poured down annually upon the surface of our earth may be formed from the fact that it exceeds a million times the heat producible by all the coal raised, which may be taken at 280,000,000 tons a year.

If, then, we depend upon solar radiation for our very existence from day to day, it cannot be said that we are only remotely interested in solar physics, and the question whether and how solar energy, comprising the rays of heat, of light, and the actinic rays, is likely to be maintained, is one in which we have at least as great a reversionary interest as we have in landed estate or other property.

If the amount of heat, or, more correctly speaking, of energy, supplied annually to our earth is great as compared with terrestrial quantities, that scattered abroad in all directions by the sun strikes us as something almost beyond conception.

The amount of heat radiated from the sun has been approximately computed by the aid of the pyrheliometer of Pouillet, and by the actinometers of Herschel, at 18,000,000 heat-units from every square foot of its surface per hour; or, expressed popularly, if coal were consumed on the surface of the sun in the most perfect manner, our total annual production of 280,000,000 tons, being the estimated produce of all the coal-mines of the earth, would suffice to keep up solar radiation for only one forty-millionth part of a second; or, if the earth were a mass of coal, and could be supplied by contract to the solar furnacemen, this supply would last them just thirty-six hours.

If the sun were surrounded by a solid sphere of a radius equal to the mean distance of the sun from the earth (95,000,000 miles), the whole of this prodigious amount of heat would be intercepted; but

considering that the earth's apparent diameter, as seen from the sun, is only seventeen seconds, the earth can intercept only the 2250-millionth part. Assuming that the other planetary bodies swell the amount of intercepted heat to ten times this amount, there remains the important fact that $\frac{2242222222}{2250000000}$ of the solar energy is radiated into space, and apparently lost to the solar system, and only $\frac{1}{2250000000}$ utilized or intercepted.

Notwithstanding this enormous loss of heat, solar temperature has not diminished sensibly for centuries, if we neglect the periodic changes, apparently connected with the appearance of sun-spots, that have been observed by Lockyer and others, and the question forces itself upon us, how this great loss can be sustained without producing an observable diminution of solar temperature, even within a human life-time.

Among the ingenious hypotheses intended to account for a continuance of solar heat is that of shrinkage or gradual reduction of the sun's volume, suggested by Helmholtz. It may, however, be argued against this theory that the heat so produced would be liberated throughout its mass, and would have to be brought to the surface by conduction, aided perhaps by convection; but we know of no material of sufficient conductivity to transmit anything approaching the amount of heat lost by radiation.

Chemical action between the constituent parts of the sun has also been suggested; but here again we are met by the difficulty that the products of such combination would, ere this, have accumulated on the surface, and would have formed a barrier against further action.

These difficulties led Sir William Thomson to the suggestion that the cause of maintenance of solar temperature might be found in the circumstance of meteorites, not falling upon the sun from great distances in space, as had been suggested by Mayer and Waterton, but circulating with an acquired velocity within the planetary distances of the sun, and he shows that each pound of matter so imported would represent a large number of heat-units, without disturbing the planetary equilibrium. But in considering more fully the enormous amount of planetary matter that would be required for the maintenance of the solar temperature, Sir William Thomson soon abandoned this hypothesis for that of simple transfer of heat from the interior of a fluid sun to the surface by means of convection-currents, which latter

hypothesis is at the present time supported by Professor Stokes and other leading physicists.

This theory has certainly the advantage of accounting for the greatest possible store of heat within the solar mass, because it supposes the latter to consist in the main of a fluid heated to such a temperature that, if it were relieved at any point of the confining pressure, it would flash into gas of a vastly inferior, but still of an elevated, temperature. It is supposed that such fluid material, or material in the "critical" condition, as Professor Thomas Andrews, of Belfast, has named it, is continually transferred to the surface by means of convection-currents, that is to say, by currents forming naturally when a fluid substance is cooled at its upper snrface, and sinks down after cooling to make room for ascending material at the comparatively higher temperature. It is owing to such convection-currents that the temperature of a room is, generally speaking, higher toward the ceiling than toward the floor, and that upon plunging a thermometer into a tank of heated water the surface temperature is found slightly superior to that near the bottom.

These convection-currents owe their existence to a preponderance of the cooled descending over the ascending current; but this difference being slight, and the ascending and descending currents intermixing freely, they are, generally speaking, of a sluggish character; hence, in all heating apparatus, it is found essential to resort either to artificial propulsion, or to separating walls between the ascending and the descending currents, in order to give effect to the convective transfer of heat.

In the case of a fluid sun another difficulty presents itself through the circumstance that the vast liquid interior is enveloped in a gaseous atmosphere, which, although perhaps some thousands of miles in depth, represents a relatively very small store of heat. Convection-currents may be supposed active in both the gaseous atmosphere and in the fluid ocean below, but the surface of this fluid must necessarily constitute a barrier between the two convective systems, nor could the convective action of the gaseous atmosphere—that is to say, the simple up and down currents caused by surface refrigeration—be such as to disturb the liquid surface below to any great extent, because each descending current would have had plenty of time to get intermixed with its neighboring ascending current, and would, therefore, have reached its least intensity on arriving on the liquid surface.

As regards the liquid, its most favorable condition for heating purposes would be at the critical point, or that at which the slightest diminution of superincumbent pressure would make it flash off into gas; but considering that, by means of conduction and convection, the liquid matter must have assumed, in the course of ages, a practically uniform temperature to a very considerable depth, it follows that the liquid below the surface, with fluid pressure in addition to that of the superimposed gaseous atmosphere, must be ordinary fluid, the critical condition being essentially confined only to the surface.

Conditions analogous to those here contemplated are met with in a high-pressure steam-boiler, with its heated water and dense vapor atmosphere. Suppose the fire below such a boiler be withdrawn, and its roof be exposed to active radiation into space, what should we observe through a strong pane of glass inserted in the side of the boiler near the liquid surface, lit up by an incandescent electric lamp within? The loss of heat by radiation from the boiler would give rise to convection-currents, and partial condensation of the vapor atmosphere; then, if the motion of the water were made visible by means of coloring matter, we should observe convection-currents in the fluid mass separate and distinct from those in the gaseous mass; but these convection-currents would cause no visible disturbance of the liquid surface, which would present itself to the eye with the smoothness of a mirror. It is only in the event of the steam-pressure being suddenly relieved at any point on the surface that a portion of the water would flash into steam, causing a violent upheaval of the liquid.

The dark spots on the sun appear to indicate commotion of this description, but these are evidently not the result of mere convection-currents; if they were, they would occur indiscriminately over the entire surface of the sun, whereas telescopic observation has revealed the fact that they do occur almost exclusively in two belts, between the equator and the polar surfaces on either side. Their occurrence could be satisfactorily explained if we could suppose the existence of strong lateral currents flowing from the polar surfaces toward the equator, which lateral currents in the solar atmosphere would cause cyclones or vortex action with a lower and denser atmosphere, consisting probably of metallic vapors; this vortex action extending downward would relieve the fluid ocean locally from pressure, and give rise to explosive outbursts of enormous magnitude, projecting the lower atmosphere high above the photosphere, with a velocity measured,

according to Lockyer, by a thousand miles a second. It will be seen from what follows how, according to my view, such vortex action in those intermediate regions of the sun would necessarily be produced.

But supposing that, notwithstanding the difficulties just pointed out, convection-currents sufficed to effect a transfer of internal heat to the surface with sufficient rapidity to account for the enormous surface-loss by radiation, we should only have the poor satisfaction of knowing that the available store would last longer than might have been expected, whereas a complete solution of the problem would be furnished by a theory, according to which the radiant energy which is now supposed to be dissipated into space and irrecoverably lost to our solar system, could be arrested and brought back in another form to the sun himself, there to continue the work of solar radiation.

Some six years ago the thought occurred to me that such a solution of the solar problem might not lie beyond the bounds of possibility, and, although I cannot claim intimate acquaintance with the intricacies of solar physics, I have watched its progress, and have engaged also in some physical experiments bearing upon the question, all of which have served to strengthen my confidence, and to ripen in me the determination to submit my views, not without some misgiving, to the touchstone of scientific criticism.

For the purpose of my theory, stellar space is supposed to be filled with highly rarefied gaseous bodies, including hydrogen, oxygen, nitrogen, carbon, and their compounds, besides solid materials in the form of dust. Each planetary body would in that case attract to itself an atmosphere depending for density upon its relative attractive importance, and it would not seem unreasonable to suppose that the heavier and less diffusible gases would form the staple of these local atmospheres; that, in fact, they would consist mostly of nitrogen, oxygen, and carbonic acid, while hydrogen and its compounds would predominate in space.

In support of this view it may be urged that, in following out the molecular theory of gases, as laid down by Clausius, Clerk Maxwell and Thomson, it would be difficult to assign a limit to a gaseous atmosphere in space; and, further, that some writers—among whom I will here mention only Grove, Humboldt, Zöllner and Mattieu Williams—have boldly asserted the existence of a space filled with matter. But Newton himself, as Dr. Sterry Hunt tells us in an interesting paper

which has only just reached me, has expressed views in favor of such an assumption.

The history of Newton's paper is remarkable and very suggestive. It was read before the Royal Society on the 9th and 16th of December, 1675, and remained unpublished until 1757, when it was printed by Birch, the then secretary, in the third volume of his "History of the Royal Society," but received no attention; in 1846 it was published in the "Philosophical Magazine" at the suggestion of Harcourt, but was again disregarded; and now, once more, only a few months since, a philosopher on the other side of the Atlantic brings back to the birthplace of Newton his forgotten and almost despised work of two hundred years ago.

Quoting from Dr. Sterry Hunt's paper:

"Newton in his Hypothesis imagines 'an ethereal medium much of the same constitution with air, but far rarer, subtler, and more elastic. . . . . But it is not to be supposed that this medium is one uniform matter, but composed partly of the main phlegmatic body of ether, partly of other various ethereal spirits, much after the manner that air is compounded of the phlegmatic body of air intermixod with various vapors and exhalations.' Newton further suggests in his Hypothesis that this complex spirit or ether, which, by its elasticity, is extended throughout all space, is in continual movement and interchange. 'For Nature is a perpetual circulatory worker, generating fluids out of solids, and solids out of fluids; fixed things out of volatile, and volatile out fixed; subtile out of gross, and gross out of subtile; some things to ascend and make the upper terrestrial juices, rivers, and the atmosphere, and by consequence others to descend for a requital to the former. And as the earth, so perhaps may the sun imbibe this spirit copiously, to conserve his shining, and keep the planets from receding further from him; and they that will may also suppose that this spirit affords or carries with it thither the solary fuel and material principle of life, and that the vast ethereal spaces between us and the stars are for a sufficient repository for this food of the sun and planets. . . . Thus, perhaps, may all things be originated from ether."

If at the time of Newton chemistry had been understood as it now is, and if, moreover, he had been armed with that most wonderful of all modern scientific instruments, the spectroscope, the direct outcome of his own prismatic analysis, there appears to be no doubt that the author of the laws of gravitation would have so developed his thoughts

upon solar fuel that they would have taken the form rather of a scientific discovery than of a mere speculation.

Our proof that interstellar space is filled with attenuated matter does not rest, however, solely upon the uncertain ground of speculation. We receive occasionally upon our earth celestial visitors termed meteorites; these are known to travel in loose masses round the sun in orbits intersecting at certain points that of our earth. When in their transit they pass through the denser portion of our atmosphere they become incandescent, and are popularly known as falling stars. In some cases they are really deserving of that name, because they strike down upon our earth, from the surface of which they have been picked up and subjected to searching examination while still warm after their exertion. Dr. Flight has only very recently communicated to the Royal Society an analysis of the occluded gases of one of these meteorites as follows:

CO_2 (Carbonic acid),	0·12
CO (Carbonic oxide),	31·88
H (Hydrogen),	45·79
CH_4 (Marsh-gas),	4·55
N (Nitrogen),	17·66
	100·00

It appears surprising that there was no aqueous vapor, considering that there was much hydrogen and oxygen in combination with carbon; but perhaps the vapor escaped observation, or was expelled to a greater extent than the other gases by external heat when the meteorite passed through our atmosphere. Opinions concur that the gases found occluded in meteorites cannot be supposed to have entered into their composition during their very short period of traversing our denser atmosphere; but, if any doubt should exist on this head, it ought to be set at rest by the fact that the gas principally occluded is hydrogen, which is not contained in our atmosphere in any appreciable quantity.

Further proof of the fact that stellar space is filled with gaseous matter is furnished by spectrum analysis, and it appears from recent investigation, by Dr. Huggins and others, that the nucleus of a comet contains very much the same gases found occluded in meteorites, including "carbon, hydrogen, nitrogen, and probably oxygen," while,

according to the views set forth by Dewar and Liveing, it also contains nitrogenous compounds, such as cyanogen.

Adversely to the assumption that interplanetary space is filled with gases, it is urged that the presence of ordinary matter would cause sensible retardation of planetary motion, such as must have made itself felt before this; but, assuming that the matter filling space is an almost perfect fluid, not limited by border surfaces, it can be shown on purely mechanical grounds that the retardation by friction through such an attenuated medium would be very slight indeed, even at planetary velocities.

But it may be contended that, if the views here advocated regarding the distribution of gases were true, the sun should draw to himself the bulk of the least diffusible, and therefore the heaviest gases, such as carbonic acid, carbonic oxide, oxygen and nitrogen, whereas spectrum analysis has proved, on the contrary, a great prevalence of hydrogen.

In explanation of this seeming anomaly, it can be shown, in the first place, that the temperature of the sun is so high that such compound gases as carbonic acid and carbonic oxide could not exist within him, their point of dissociation being very much below the solar temperature. It has been contended, indeed, by Mr. Lockyer, that none of the metalloids have any existence at these temperatures, although as regards oxygen Dr. Draper asserts its existence in the solar photosphere. There must be regions, however, outside that thermal limit, where their existence would not be jeopardized by heat; and here great accumulation of the comparatively heavy gases that constitute our atmosphere would probably take place, were it not for a certain counterbalancing action.

I here approach a point of primary importance in my argument, upon the proof of which my further conclusions must depend.

The sun completes one revolution on its axis in twenty-five days, and its diameter being taken at 882,000 miles, it follows that the tangential velocity amounts to 1·25 miles per second, or to what the tangentical velocity of our earth would be if it occupied five hours instead of twenty-four in accomplishing one revolution. This high rotative velocity of the sun must cause an equatorial rise of the solar atmosphere, to which Mairan, in 1731, attributed the appearance of zodiacal light. Laplace rejected this explanation on the ground that zodiacal light extended to a distance from the sun exceeding our own,

whereas the equatorial rise of the solar atmosphere due to its rotation could not exceed nine-twentieths of the distance of Mercury. But it must be remembered that Laplace based his calculation upon the generally accepted hypothesis of an empty stellar space (occupied only by an imaginary ether), and it can be shown that the result of solar rotation would be widely different, if supposed to take place within a medium of unbounded extension. In this case pressures would be balanced all round, and the sun would act mechanically upon the floating matter surrounding him in the manner of a fan, drawing it toward himself upon the polar surfaces, and projecting it outward in a continuous disk-like stream from the equatorial surfaces.

By this fan action, hydrogen, hydrocarbons, and oxygen are supposed to be drawn in enormous quantities toward the polar surfaces of the sun; during the gradual approach they pass from their condition of extreme attenuation and intense cold to that of compression, accompanied with increase of temperature, until, on approaching the photosphere, they burst into flame, giving rise to a great development of heat, and a temperature commensurate with their point of dissociation at the solar density. The result of their combustion will be aqueous vapor and carbonic acid, and these products of combustion, in yielding to the influence of centrifugal force, will flow toward the solar equator, and be thence projected into space.

In view of the importance of this centrifugal action for the purpose of my theory, the following simple mathematical statement of the problem may not be thought out of place: Let us consider the condition of two equal gaseous masses, at equal distances from the solar center, the one in the direction of the equator, the other in that of either of the poles. These two masses would be equally attracted toward the sun, and balance one another as regards the force of gravitation, but the former would be subject to another force, that of centrifugal action, which, however small in amount as compared with the enormous attraction of the sun, would destroy the balance, and determine a motion toward the sun as regards the mass opposite the polar surface, and into space as regards the equatorial mass. The same action would take effect upon the masses filling their places, and the result must be a continuous current depending for its velocity upon the rate of solar rotation. The equatorial current so produced, owing to its mighty proportions, would flow outward into space, to a practically unlimited distance.

The next question for consideration is, What would become of these products of combustion when thus returned into space? Apparently they would gradually change the condition of stellar material, rendering it more and more neutral; but I venture to suggest that the possibility, nay, the probability, that solar radiation will, under these conditions, step in to bring back the combined materials to a state of separation by dissociation carried into effect at the expense of that solar energy which is now supposed to be irrevocably lost or dissipated into space, as the phrase goes.

According to the law of dissociation as developed by Bunsen and Sainte-Claire Deville, the point of decomposition of different compounds depends upon the temperature on the one hand, and upon the pressure on the other. According to Sainte-Claire Deville, the dissociation tension of aqueous vapor at atmospheric pressure and at 2,800°C. is 0·5, that is to say one-half of the vapor would exist as such, the remaining half being found as a mechanical mixture of hydrogen and oxygen; but, with the pressure, the temperature of dissociation rises and falls, as the temperature of saturated steam rises and falls with its pressure. It is therefore conceivable that the solar photosphere may be raised by combustion to a temperature exceeding 2,800°C., whereas dissociation may be effected in space at a lower temperature. This temperature of 2,800° would be quite sufficient to account for the character and amount of solar radiation, if it is only borne in mind that the luminous atmosphere may be a thousand miles in depth, and that the flame of hydrogen and hydrocarbons, in the uppermost layers of this zone, is transparent to the radiant energy produced in the layers below, thus making the total radiation rather the sum of matter in combustion than the effect of a very intensely heated surface.

Sainte-Claire Deville's investigations had reference only to heats measured by means of pyrometers, but do not extend to the effects of radiant heat. Dr. Tyndall has shown by his important researches that vapor of water and other gaseous compounds intercept radiant heat in a most remarkable degree, and there is other evidence to show that radiant energy from a source of high intensity possesses a dissociating power far surpassing the measurable temperature to which the compound substance under its influence is raised. Thus carbonic acid and water are dissociated in the leaf-cells of plants under the influence of the direct solar ray at ordinary summer temperature, and experi-

ments in which I have been engaged for nearly three years* go to prove that this dissociating action is obtained also under the radiant influence of the electric arc, although it is scarcely perceptible if the energy is such as can be produced by an inferior source of heat.

The point of dissociation of aqueous vapor and carbonic acid admits, however, of being determined by direct experiment. It engaged my attention some years ago, but I have hesitated to publish the qualitative results I then obtained, in the hope of attaining to quantitative proofs.

These experiments consisted in the employment of glass tubes furnished with platinum electrodes, and filled with aqueous vapor or with carbonic acid in the usual manner, the latter being furnished with caustic soda to regulate the vapor-pressure by heating. Upon immersing one end of the tube charged with aqueous vapor in a refrigerating mixture of ice and chloride of calcium, its temperature at that end was reduced to —32°C., corresponding to a vapor-pressure, according to Regnault, of $\frac{1}{1800}$ of an atmosphere. When so cooled no slow electric discharge took place on connecting the two electrodes with a small induction-coil. I then exposed the end of the tube projecting out of the freezing mixture, backed by white paper, to solar radiation (on a clear summer's day) for several hours, when, upon again connecting up to the inductorium, a discharge, apparently that of a hydrogen vacuum, was obtained. This experiment being repeated furnished unmistakable evidence, I thought, that aqueous vapor had been dissociated by exposure to solar radiation. The carbonic-acid tubes gave, however, less unmistakable effects. Not satisfied with these qualitative results, I made arrangements to collect the permanent gases so produced by means of a Sprengel pump, but was prevented by lack of time from pursuing the inquiry, which I propose, however, to resume shortly, being of opinion that, independently of our present speculation, the experiments may prove useful in extending our knowledge regarding the laws of dissociation.

It should be here observed that, according to Professor Stokes, the ultra-violet rays are in large measure absorbed in passing through clear glass, and it follows from this discovery that only a small portion of the chemical rays found their way through the tubes to accomplish the

* See *Proceedings Royal Society*, vol. xxx, March 1, 1880; also a paper read before Section A of the British Association, September 1, 1881, and ordered to be printed in the report.

work of dissociation. This circumstance being adverse to the experiment only serves to increase the value of the effect observed, while it appears to furnish additional proof of the fact, first enunciated by Professor Draper, and corroborated by my own experiments on plants, that the dissociating power of light is not confined to the ultra-violet rays, but depends in the process of vegetation chiefly upon the yellow and red rays.

Assuming, for my present purpose, that dissociation of aqueous vapor was really effected in the experiment just described, and assuming, further, that stellar space is filled with aqueous and other vapors of a density not exceeding the $\frac{1}{2000}$ part of our atmosphere, it seems reasonable to suppose that its dissociation would be effected by solar radiation, and that solar energy would thus be utilized. The conjoint presence of aqueous vapor, carbonic acid and nitrogen would only serve to facilitate their decomposition, in consequence of the simultaneous formation of hydrocarbons and nitrogenous compounds by combination of the nascent hydrogen and the nitrogen with carbon in a manner analogous to what occurs in vegetation. It is not necessary to suppose that all the energy radiated from the sun into space should be intercepted, inasmuch as even a partial return of heat in the manner described would serve to supplement solar radiation, the balance being made up by absolute loss. To this loss of energy would have to be added that consumed in sustaining the circulating current, which, however, need not relatively be more than what is known to be lost on our earth through the tidal action, and may be supposed to be compensated as regards the time of solar rotation by gradual shrinkage.

By means of the fan-like action resulting from the rotation of the sun, the vapors dissociated in space to-day would be drawn toward the polar surfaces of the sun to-morrow, be heated by increase in density, and would burst into flame at a point where both their density and temperature had reached the necessary elevation to induce combustion, each complete cycle taking, however, years to be accomplished. The resulting aqueous vapor, carbonic acid and carbonic oxide would be drawn toward the equatorial regions, and be then again projected into space by centrifugal force.

Space would, according to these views, be filled with gaseous compounds in process of decomposition by solar radiant energy, and the existence of these gases would furnish an explanation of the solar

absorption spectrum, in which the lines of some of the substances may be entirely neutralized and lost to observation. As regards the heavy metallic vapors revealed in the sun by the spectroscope, it is assumed that these form a lower and denser solar atmosphere, not participating in the fan-like action which is supposed to affect the light outer atmosphere only, in which hydrogen is the principal factor.

Such a dense metallic atmosphere could not participate in the fan action affecting the lighter photosphere, because this is only feasible on the supposition that the density of the inflowing current is, at equal distances from the gravitating centre, equal or nearly equal to the outflowing current. It is true that the products of combustion of hydrogen and hydrocarbon are denser than their constituents, but this difference may be balanced by their superior temperature on leaving the sun, whereas the metallic vapors would be unbalanced, and would therefore obey the laws of gravitation, recalling them to the sun. On the surface of contact between the two solar atmospheres, intermixture induced by friction must take place, however, giving rise to those vortices and explosive effects within the zones of the sun, between the equator and the polar surfaces, to which reference has already been made in this article; these may appropriately be called the "stormy regions" of the sun, which were first observed and commented upon by Sir John Herschel. Some of the denser vapors would probably get intermixed, be carried away mechanically by the lighter gases, and give rise to that cosmic dust observed to fall upon our earth in not inappreciable quantities, and generally assumed hitherto to be the *débris* of broken meteorolites. Excessive intermixture between the heat-producing atmosphere and the metallic vapors below appears to be prevented by the existence of an intermediate neutral atmosphere, and called the penumbra.

As the whole solar system moves through space at a pace estimated at 150,000,000 miles annually (being about one-fourth of the velocity of the earth in its orbit), it appears possible that the condition of the gaseous fuel supplying the sun may vary according to its state of previous decomposition, in which other heavenly bodies may have taken part, and whereby an interesting reflex action between our sun and other heavenly bodies would be brought about. May it not be owing to such differences in the quality of the fuel supplied that the observed variations of the solar heat may arise?—and may it not be in consequence of such changes in the thermal condition of the photo-

sphere that the extraordinary convulsions revealed to us as sun-spots occur?

The views here advocated could not be thought acceptable unless they furnish at any rate a consistent explanation of the still somewhat mysterious phenomena of the zodiacal light and of comets. Regarding the former, we should be able to revert to Mairan's views, the objection by Laplace being met by a continuous outward flow from the solar equator. Luminosity would be attributable to particles of dust emitting light reflected from the sun, or to phosphorescence. But there is another cause for luminosity of these particles, which may deserve serious consideration. Each particle would be electrified by gaseous friction in its acceleration, and its electric tension would be vastly increased in its forcible removal, in the same way as the fine dust of the desert has been observed by Dr. Werner Siemens to be in a state of high electrification on the apex of the Cheops Pyramid. Could not the zodiacal light also be attributed to slow electric discharge backward from the dust toward the sun?—and would not the same cause account for a great difference of potential between the sun and earth, which latter may be supposed to be washed by the solar radial current? May not the presence of the radial solar current also furnish us with an explanation of the fact that hydrogen, while abounding apparently in space, is practically absent in our atmosphere, where aqueous vapor and carbonic acid, which would come to us directly from the sun, take its place? An action analogous to this, though on a much smaller scale, may be set up also by terrestrial rotation, giving rise to an electrical discharge from the outgoing equatorial stream to the polar regions, where the atmosphere to be pierced by the return flood is of least resistance. Thus the phenomenon of the aurora borealis or northern lights would find an easy explanation.

The effect of this continuous outpour of solar materials could not be without very important influences as regards the geological conditions of our earth. Geologists have long acknowledged the difficulty of accounting for the amount of carbonic acid that must have been in our atmosphere, at one time or another, in order to form with lime those enormous beds of dolomite and limestone, of which the crust of our earth is in great measure composed. It has been calculated that, if this carbonic acid had been at one and the same time in our atmosphere, it would have caused an elastic pressure fifty times that of our present atmosphere; and, if we add the carbonic acid that

must have been absorbed in vegetation in order to form our coal-beds, we should probably have to double that pressure. Animal life, of which we find abundant traces in these "measures," could not have existed under such conditions, and we are almost forced to the conclusion that the carbonic acid must have been derived from an external source.

It appears to me that the theory here advocated furnishes a feasible solution of this geographical difficulty. Our earth being situated in the outflowing current of the solar products of combustion, or, as it were, in the solar chimney, would be fed from day to day with its quota of carbonic acid, of which our local atmosphere would assimilate as much as would be necessary to maintain it in a carbonic-acid vapor density balancing that of the solar current; we should thus receive our daily supply of this important constituent (with the regularity of fresh rolls for breakfast), which, according to an investigation by M. Reiset, communicated to the French Academy of Sciences by M. Dumas on the 6th of March last, amounts to the constant factor of one ten-thousandth part of our atmosphere. The aqueous vapor in the air would be similarly maintained as to its density, and its influx to, or reflux from, our atmosphere would be determined by the surface temperature of our earth.

It is also important to show how the phenomena of comets could be harmonized with the views here advocated, and I venture to hope that these occasional visitors will serve to furnish us with positive evidence in my favor. Astronomical physicists tell us that the nucleus of a comet consists of an aggregation of stones similar to meteorites. Adopting this view, and assuming that the stones have absorbed in stellar space gases to the amount of six times their volume, taken at atmospheric pressure, what, it may be asked, will be the effect of such a divided mass advancing toward the sun at a velocity reaching in perihelion the prodigious rate of 366 miles per second (as observed in the comet of 1845), being twenty-three times our orbital rote of motion? It appears evident that the entry of such a mass into a comparatively dense atmosphere must be accompanied by a rise of temperature by frictional resistance, aided by attractive condensation. At a certain point the increase of temperature must cause ignition, and the heat thus produced must drive out the occluded gases, which in an atmosphere 3,000 times less dense than that of our earth would produce $6 \times 3{,}000 = 10{,}000$ times the volume of the stones themselves.

These gases would issue forth in all directions, but would remain unobserved except in that of motion, in which they would meet the interplanetary atmosphere with the compound velocity, and form a zone of intense combustion, such as Dr. Huggins has lately observed to surround the one side of the nucleus, evidently the side of forward motion. The nucleus would thus emit original light, whereas the tail may be supposed to consist of stellar dust rendered luminous by reflex action produced by the light of the sun and comet combined, as foreshadowed already by Tyndall, Tait, and others, starting each from different assumptions.

Although I cannot pretend to an intimate acquaintance with the more intricate phenomena of solar physics, I have long had a conviction, derived principally from familiarity with some of the terrestrial effects of heat, that the prodigious dissipation of solar heat is unnecessary to satisfy accepted principles regarding the conservation of energy, but that solar heat may be arrested and returned over and over again to the sun, in a manner somewhat analogous to the action of the heat recuperator in the regenerative engine and gas-furnace. The fundamental conditions are:

1. That aqueous vapor and carbon compounds are present in stellar or interplanetary space.

2. That these gaseous compounds are capable of being dissociated by radiant solar energy while in a state of extreme attenuation.

3. That the vapors so dissociated are drawn toward the sun in consequence of solar rotation, are flashed into flame in the photosphere, and rendered back into space in the condition of products of combustion.

Three weeks have now elapsed since I ventured to submit these propositions to the Royal Society for scientific criticism, and it will probably interest my readers to know what has been the nature of that criticism and the weight of additional evidence for or against my theory.

Criticism has been pronounced by mathematicians and physicists, but affecting singularly enough the chemical and not the mathematical portion of my argument; whereas chemists have expressed doubts regarding my mathematics while accepting the chemistry involved in my reasoning.

Doubts have been expressed as to the sufficiency of the proof that dissociation of attenuated aqueous vapor and carbonic acid is really

effected by radiant solar energy, and, if so effected, whether the amount of heat so supplied to the sun could be at all adequate in amount to keep up the known rate of radiation. It was admitted in my paper that my own experiments on the dissociation of vapors within vacuous tubes amounted to inferential rather than absolute proof; but the amount of inferential evidence in favor of my views has been very much strengthened since by chemical evidence received from various sources; and I will here only refer to one of these.

Professor Piazzi Smyth, the Astronomer Royal for Scotland, has, in connection with Professor Herschel, of Newcastle, recently presented an elaborate paper or series of papers to the Royal Society of Edinburgh "On the Gaseous Spectra in Vacuum-Tubes," of which he has kindly forwarded me a copy. It appears from these memoirs that when vacuum-tubes, which contain attenuated vapors, have been laid aside for a length of time, they turn practically into hydrogen-tubes. In another very recent paper presented to the Royal Society of Edinburgh, Professor Piazzi Smyth furnishes important additional proof of the presence of oxygen in the outer solar atmosphere, and gives an explanation why this important element has escaped observation by the spectroscope. Additional proof of the existence of oxygen in the outer solar atmosphere has been given by Professor Stoney, the Astronomer Royal for Ireland, and by Mr. R. Meldola in an interesting paper communicated by him to the "Philosophical Magazine," in June, 1878.

As regards the sufficiency of an inflowing stream of dissociated vapors to maintain solar energy, the following simple calculation may be of service: Let it be assumed that the stream flowing in upon the polar surfaces of the sun flashes into flame when it has attained the density of our atmosphere, that its velocity at that time is 100 feet per second (the velocity of a strong terrestrial wind), and that in its composition only one twentieth part is hydrogen and marsh-gas in equal proportions, the other nineteen twentieths being made up of oxygen, nitrogen and neutral compounds. It is well known that each pound of hydrogen develops in burning about 60,000 heat-units, and each pound of marsh-gas about 24,000; the average of the two gases mixed in equal proportion would yield, roughly speaking, 42,000 units; but, considering that only one-twentieth part of the inflowing current is assumed to consist of such combustible matter, the amount of heat developed per pound of inflowing current would be only 2100 heat-

units. One hundred cubic feet, weighing eight pounds, would enter into combustion every second upon each square foot of the polar surface, and would yield $8 \times 60 \times 60 \times 2{,}100 = 60{,}480{,}000$ heat units per hour. Assuming that one-third of the entire solar surface may be regarded as polar heat-receiving surface, this would give 20,000,000 heat-units per square foot of solar surface; whereas, according to Herschel's and Pouillet's measurements, only 18,000,000 heat-units per square foot of solar surface are radiated away. There would thus be no difficulty in accounting for the maintenance of solar energy from the supposed source of supply. On the other hand, I wish to guard myself against the assumption that appears to have been made by some critics, that what I have advocated would amount to the counterpart of "perpetual motion," and therefore to an absurdity. The sun cannot of course get back any heat radiated by himself which has been turned to a purpose; thus the solar heat spent upon our earth in effecting vegetation must be absolutely lost to him.

My paper presented to the Royal Society was accompanied by a diagram of ideal corona, representing an accumulation of igneous matter upon the solar surfaces, surrounded by disturbed regions pierced by occasional vortices and outbursts of metallic vapors, and culminating in two outward streams projecting from the equatorial surfaces into space through many thousands of miles. The only supporting evidence in favor of this diagram were certain indications that may be found in the instructive volume on the sun by Mr. R. A. Proctor. It was therefore a matter of great satisfaction to me to be informed, as I have been by an excellent authority and eye-witness, that my imaginary diagram bore a very close resemblance to the corona observed in America on the occasion of the total eclipse of the sun on the 11th of January, 1880.

Enough has been said, I think, to prove that the theory I have ventured to put forward is the result, at any rate, of considerable reflection; and I may add that, since its first announcement, I have not seen reason to reject any of the links of my chain of argument: these I have here endeavored to strengthen only by additional facts and explanations.

Miracle at the Bar of Science.—In the preface to the fifth volume of *Les Splendeurs de la Foi* Abbe Moigno recounts the several steps of the Roman Catholic church in arriving at the canonization of St. Benoit-Joseph Labre. The preliminary investigation began June 6, 1783, and ended September 22, 1785. The records of this investigation cover 3300 pages. Subsequent examinations occurred at various periods, and the canonization was finally completed on April 16, 1875. Pope Leo XIII has authorized the venerable Abbe to embody an account of the entire process in a volume of his series, and the attention of physicians and other scientific men is invited to the evidence which is presented, and the care which was taken at every step to avoid the possibility of deception.—*Les Mondes*, Supplement, April 29, 1882. C.

Subterranean Tide.—Chase's views, with regard to the influence of electricity upon tidal phenomena (*Proc. Amer. Phil. Soc.*, vol. ix) have been confirmed by late investigations of M. C. Lagrange. In a communication to *Ciel et Terre* he says: "Whatever resistance may be opposed by a body to distortion, when it is influenced by certain forces, the resistance is not infinite, and the most tenacious bodies undergo in these circumstances a change in their dimensions; moreover, these variations of dimensions are proportional to the dimensions themselves. Hence it happens that bodies of a considerable volume may undergo appreciable distortions, however slight may be their extensions or compressions for a unit of length." Chase has shown (*Proc. Amer. Phil. Soc.*, April 21, 1882, note 217) that all the tidal tendencies which are due to solar and lunar action may be satisfied by a change in the distance between any two molecular centres which is less than $\frac{1}{4000000}$ of their mean distance. F. W. Klonne has studied the tidal movements of the subterranean waters which invaded the mines of Dux, in Bohemia, in the year 1879. Guilio Grablowitz, who has been long engaged in tidal investigations, and who has especially investigated the tidal anomalies of the Adriatic, has discussed the observations of M. Klonne, and finds that while they are influenced by the sun and moon, that influence is mainly exerted upon the solid portions of the globe. Lagrange quotes largely from the memoir of Grablowitz, gives some comparative tables and suggestions, which seem likely to lead to important modifications of tidal theories.—*Ann. de Chim. et de Phys.*, April, 1882. C.

A New Variety of Glass.—The *Wiener Gewerbe-Zeitung* states that a chemist of Vienna has invented a new kind of glass, which contains no silex, potash, soda, lime, nor borax. In appearance it is equal to the common crystal, but more brilliant; it is perfectly transparent, white and clear, and can be cut and polished. It is completely insoluble in water and is not attacked by fluoric acid, but it can be corroded by hydrochloric and nitric acid. When in a state of fusion it adheres to iron, bronze and zinc.—*Gaceta Industrial.* C.

Improvement in Grain Elevators.—The port of Bordeaux, like those of Havre and Marseilles, is to be provided with boat elevators for mechanically unloading grain vessels. The steam motor is replaced by an electric motor. This change allows the boats to be employed during the day for unloading grain, while during the night they are changed into lighthouses, for produciag a powerful electric illumination of the harbor. These movable electric lighthouses will also serve, during the approaching exposition, for the nautical festivals upon the river at night.—*La Lumière Electrique*, vi, 359. C.

Electric Transmission of Power.—J. Chrétien states that the first attempt to transmit motive power by electricity was made in 1873, at the Vienna Exposition, by H. Fontaine. In 1876, at Philadelphia, and in 1878, at Paris, the experiment was repeated. Patents were afterward taken out by Chrétien and by Felix for the application of this mode of transmission to cranes and hoisting apparatus. Important experiments upon ploughing by electricity were made at Sermaize, early in 1879, and since that period great progress has been made in pumping, pile-driving, punching, sawing, sewing, embroidering, weaving, printing, etc. He thinks that it is safe to calculate upon the transmission of 50 per cent. of the whole power. Falls and watercourses, when properly regulated, would allow the utilization of a considerable motive force, at the same time that they favored irrigation and diminished the probability of disastrous freshets. Tides and windmills, in spite of the intermittence of their labor, may be advantageously used through the help of accumulators. Solar heat, when transformed into electrteity, seems to offer a more desirable solution than the direct application to the production of steam. Coal can be more profitably employed under large boilers, which supply powerful and well-perfected motors, at a moderate rate of consumption, than under smaller boilers, which consume from five to thirty times as much fuel per horse-power.—*Soc. des Ecoles d'Arts et Mét.* C.

Franklin Institute.

HALL OF THE INSTITUTE, May 24, 1882.

A special meetiing of the Institute was held this evening at 8 o'clock, to consider the subject of pending legislation in Congress affecting property in patents.

There were present 72 members and 4 visitors.

In the absence of the President and Vice Presidents, Mr. Hector Orr was called upon to act as President *pro tem.*

The Secretary then read the following official order for the meeting, viz.:

HALL OF THE FRANKLIN INSTITUTE, May 19, 1882.

A special meeting of the Institute will be held on Wednesday evening, 24th inst., at 8 o'clock, to take into consideration the subject embraced in the following application addressed to the President.

"*Philadelphia*, May 18, 1882.

"DEAR SIR:—The undersigned members of the Franklin Institute respectfully request the calling of a special meeting of the Institute, to be held on next Wednesday evening, 24th inst., to give expression of its views on the proposition now pending before Congress, to amend the patent laws in the manner set forth in the bill passed by the House of Representatives on Monday, 15th inst.

"Very respectfully,

"H. R. HEYL,	WM. L. DUBOIS,
"HECTOR ORR,	J. E. SHAW,
"LEWIS H. SPELLIER,	JOHN A. WIEDERSHEIM,
"CHAS. E. RONALDSON,	C. HENRY RONEY,
"WM. B. COOPER,	RAPER HOSKINS,
"G. MORGAN ELDRIDGE,	LEWIS S. WARE."

In obedience to Article XII of the by-laws.

W. P. TATHAM, *President.*

The following is the text of the bill referred to, viz.:

"An Act to amend section forty-nine hundred and nineteen of the Revised Statutes, relating to the recovery of damages for the infringement of patents.

"Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That no action for damages or proceeding in equity shall be sustained, nor shall the party be held liable under sections 4919 and 4921 of the Revised Statutes of the United States, for the use of any patented article or device, when it shall appear on the trial that the defendant in such action or proceeding purchased said article for a valuable consideration in the open market."

The President *pro tem.* called attention to a copy of bill printed in large characters and suspended in the Hall for convenience of reference, and invited a free and full expression of opinion preparatory to taking definite action in relation to it.

The subject was thereupon discussed in all its bearings *pro* and *con.*, by the following gentlemen, namely: Thomas Shaw, Geo. R. Moore, Wm. B. Cooper, Prof. E. J. Houston, Amos Stevens, C. F. Reed, Cyrus Phillips, A. de Beaumont, C. H. Chormann, J. E. Mitchell, Henry R. Heyl, and G. Morgan Eldridge, the prevailing sentiment among the speakers being that of strong opposition to the proposed amendment to the patent laws.

At the close of the discussion Mr. Heyl moved that a committee of three be appointed by the Chair to express the sense of the meeting on the subject. The motion was carried, and the following members were named to constitute the committee, viz.: H. R. Heyl, Thos. Shaw and G. M. Eldridge.

The committee, after a brief deliberation, presented the following preamble and resolutions, viz.:

"WHEREAS, By the vote of the House of Representatives of the United States, taken on the 15th day of May, 1882, a bill was passed to amend the United States Patent Laws—which amendment takes away almost the entire protection granted by letters patent to property acquired by invention, and in effect legalizes theft; and

"WHEREAS, It is manifest that any such enactment as will relieve the possessor of a fraudulently made article from all liability as a party to the infringement, will render the protection heretofore guaranteed by letters patent as utterly inadequate as though no patent existed; and

"WHEREAS, The unparalleled advances that have been made by this nation in every department of science and industry are due solely and unquestionably to the wise provisions of our patent laws, and all